Airport Improvements and Urban Growth

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Abstract

This paper estimates the effects of airports on economic growth in the local areas they serve, using data from US metropolitan areas. It applies a novel identification technique that uses the overall development of the air transport network to identify changes in airport size that are not influenced by local factors. Airport size is found to have positive effects on local employment with an elasticity of 0.02 and on GDP with an elasticity of 0.035. This means that for every job created at the airport by an exogenous increase in traffic, there are three jobs created outside of the airport. Airport size is also found to have positive effects on local wages and on the number of firms. In addition there is a positive effect on the employment rate, the magnitude of which suggests that around half of jobs created by airport expansion represent a net increase in the employment of existing residents, while half are taken up by workers who migrate to the area.

Keywords: Transportation infrastructure, Air travel, Urban growth

JEL classification: H54, L93, R11, R42

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1 Introduction

Public spending on airports is motivated by a belief that improved air travel services will have a positive effect on economic growth in the areas that they serve. In the US, annual federal spending on the air travel network is around $15 billion, with further contributions by state and local governments.[1] The justification for this spending almost universally includes statements about the potential of a new or improved airport to attract firms and increase employment. However, there is little empirical basis for these claims. The purpose of this paper is to clarify what effects airports have on local economic activity.

The primary exercise I conduct is to estimate the effects of airport size on employment and gross domestic product (GDP) in US metropolitan areas. These effects are of obvious importance in evaluating policy but are challenging to estimate. The main difficulty with estimating the effects of airports on local economic outcomes is that the local economy is likely to affect airport size through the demand that it creates for air travel and the actions of policy makers. In addition, both the local economy and air traffic can be simultaneously affected by external factors. An observed correlation between airport size and economic outcomes is therefore likely to capture factors other than the causal effect of airports that is of interest.

To measure the causal effect of a change in airport size on the local economy, it is necessary to find a source of variation in airport sizes that is not driven by or otherwise correlated with local economic outcomes. This is difficult in the case of airports because actual decisions about airport improvements are normally made in response to local factors, the cost of airport construction precludes conducting experiments, and air travel is only barely dependent on external factors that vary by location such as physical geography or climate. The approach I adopt is to use variation in airport size driven by overall changes in the air travel network to construct a set of instruments for changes in air travel. I then compare the changes in airport size explained by the instruments with changes in local economic outcomes to generate estimates that reflect the causal effects of airports.

The instruments are constructed using various characteristics of the air travel network and

[1] The annual budgets of the Federal Aviation Administration from 2013 to 2015 are each between $15 billion and $16 billion, which is used to fund airport construction and maintenance, operations, and research and development (United States Department of Transportation, 2014).

overall changes in those characteristics in a method similar to that proposed by Bartik (1991) for changes in local employment. Each instrument is calculated by taking the shares of local air traffic by a certain category, then applying the national growth rate of that category to the local area. The categories used are the airline, the aircraft type, and the approximate distance of the flight. To prevent the overall growth rates from being influenced by traffic at the airports they are applied to, flights to and from a metropolitan area are excluded from the calculation of the overall growth rate applied to it.

Airport size is found to have a positive effect on local employment, with an elasticity of 0.02. In a metropolitan area with one million residents and a typically-sized airport, this means that a 10% increase in air traffic leads to the creation of approximately 750 new jobs. There is a positive effect of airport size on GDP with an elasticity of 0.035, somewhat larger than the effect on employment, so airport size appears to have a positive effect on output per worker.

I find positive effects of airport size on a range of other economic outcomes including wages, the number of firms, and the employment rate. The positive effect on wages suggests that local employment is affected at least in part through changes in productivity, rather than workers simply being attracted to the metropolitan area by the amenity value of the airport. The magnitude of the effect on the employment rate suggests that approximately half of the new jobs created represent a net increase in employment for existing residents, while half are taken up by people who migrate to the metropolitan area to take up the jobs. The effect of airports on local employment appear to be driven by changes in certain industries. Namely, there is a positive effect on employment in construction and services, but no effect on manufacturing, wholesale and retail trade, or transportation and utilities.

To further understand how the local economy is affected by changes in airport size, I study how the effects on employment and production vary by location within a metropolitan area. Airport size is found to be correlated with employment and GDP in all parts of the metropolitan area, but the causal effect of airports is concentrated in the parts of the metropolitan area that are nearer the airport. It seems reasonable that residents of all parts of the metropolitan area will use the airport, so the correlation between employment at all parts of the metropolitan area and airport size may be due to air traffic being driven by demand. However, the concentration of the causal effect in areas nearer the airport suggests that proximity is important to firms that make use of air travel.

The principal measure of airport size used in this paper is the number of departing flights. This measure is intended to reflect the physical size of the airport but also the convenience of travel – the range of destinations and the frequency of flights to a given destination – for an individual traveler. The number of seats on departing flights, the number of passengers, and an air access measure that accounts for the sizes of the destinations are also used. In applying the results to policy evaluation it is therefore necessary to consider that the results concern 'airport size' in the sense of increased traffic. To estimate the effects of a physical airport improvement, the associated increase in air traffic must therefore be assessed. On the other hand, the results apply to any policies that attract airlines to operate at an airport, even if not associated with improvements in physical infrastructure.

The main contribution of this paper is in quantifying the effects of airport improvements. The literature on the effects of airports remains small, due in part to the empirical challenges involved. Brueckner (2003), Green (2007), Blonigen and Cristea (2012), and McGraw (2014) estimate the effects of airports on local economic growth. These studies all find positive effects, with magnitudes somewhat larger than the estimates presented in this paper. Brueckner (2003) and Sheard (2014) estimate the effects of airports on particular sectors and find that the effects are most pronounced for service industries. LeFors (2014) estimates the effects of air accessibility – defined as the sizes of the markets flown to weighted for the cost of flying to those markets – and finds a positive effect on employment in tradable services but no effect on overall employment.

The literature on the effects of other types of transportation infrastructure is more advanced. Duranton and Turner (2012) find a positive effect of roads within a metropolitan area on employment growth and Duranton, Morrow and Turner (2014) find a positive effect on exports of heavier goods. For regional rather than urban growth, Michaels (2008) finds a positive effect of road connections, while Donaldson (forthcoming) and Donaldson and Hornbeck (2011) identify positive effects of railway connections.

The second contribution of this paper is methodological, in that it presents a novel and useful method for estimating the effects of airports and other types of infrastructure. The literature on the effects of airports relies mostly on physical geography, historical policy decisions, and hub status to generate exogenous variation in infrastructure. Brueckner (2003) and Green (2007) use distance to the geographical midpoint of the US to explain airport sizes, as more central locations are advantageous for hubs. Blonigen and Cristea (2012) use the removal of restrictions by the 1978 deregulation of US air travel to explain variation in air traffic levels. Sheard (2014) uses the 1944 National Airport Plan to instrument for current airport sizes. McGraw (2014) uses the 1922 Army Air Service Proposed System of Air Routes and 1938 Air Mail routes to instrument for smaller communities having airports. Brueckner (2003) and LeFors (2014) use hub status to instrument for airport size, as the demand for tickets that transfer through an airport should not be related to local demand, though local demand may influence airlines' decisions about where to locate their hubs. Similar techniques are employed in the work cited above on the effects of roads and railways – see Redding and Turner (2015) for a detailed summary.

In contrast, the technique proposed in this paper makes use of the structure of the air travel network and broad changes in its operation to generate variation in airport size that is exogenous to local economic conditions. The technique could be used to study other consequences of airport investment and airlines' decisions about where to operate. Furthermore, it could be applied to the study of other types of transportation infrastructure such as roads, railways, waterways, and ports. In many situations the technique would be easier to apply than approaches that rely on historical data or exogenous policy changes. The technique also has advantages for policy analysis as it allows the measurement of short-term effects, whereas effects explained by geography or historical decisions may have taken decades to accumulate.

The remainder of this paper is arranged as follows. The model is outlined in Section 2. The data are presented in Section 3, with a description of how the instruments are constructed. The results of the estimation are presented in Section 4. Concluding remarks are presented in Section 5.

2 Model

This section outlines the model that is used a the basis for the estimation. The model is a simple representation of how the instruments relate to airport size and how airport size relates to local economic outcomes. For brevity the model is explained in terms of an effect of airport size on employment, though it is also used to estimate the effects on GDP and other outcome variables.

2.1 Local employment

The size of the airport in metropolitan area m at time t is denoted $A_{m,t}$. The productivity of local firms may be affected by the size of the airport, which provides access to markets to source inputs and sell products. The wage earned by each worker in metropolitan area m at time t is assumed to be a function $w(A_{m,t})$ of the airport size $A_{m,t}$. The airport may also confer a direct amenity benefit to individuals in the metropolitan area, which is represented in money-metric terms by the function $g(A_{m,t})$. Both wages and the amenity value are also affected by various local and time-specific factors, which I return to below.

Larger cities are assumed to be more costly to live in, in terms of housing and commuting costs, so the cost of living in metropolitan area m at time t is described by a function $c\left(N^{\star}_{m,t}\right)$, where $c' > 0$ and $N^{\star}_{m,t}$ is the natural level of employment.

Individuals gain utility from consumption, which they do to a level determined by wage income less the cost of living. The factors besides the airport that affect wages, the cost of living, and amenities are combined in the permanent local factors μ_m and time-variant economy-wide factors ν_t. The utility of an individual living in metropolitan area m at time t is thus represented by the following, in which $u(x)$ is some monotonically increasing function of x:

$$u\left(w(A_{m,t}) + g(A_{m,t}) - c\left(N^{\star}_{m,t}\right) + \mu_m + \nu_t\right) \tag{1}$$

Individuals are assumed to be able to migrate freely between metropolitan areas and to obtain the reservation utility $\bar{u}$ by living elsewhere, which thus represents the equilibrium level of utility.[2] Let $\bar{x}$ be the combined level of consumption and amenities that provides the reservation level of

[2] The reservation utility is assumed to be time invariant and not to depend on airport infrastructure. It could be argued that airport construction could increase overall productivity or amenities, increasing the reservation utility. However, any such national-level effect would be captured by the time-specific factor ν_t.

utility, such that $u(\bar{x}) \equiv \bar{u}$. The utility function (1) and migration condition thus imply:

$$w(A_{m,t}) + g(A_{m,t}) - c\left(N^{\star}_{m,t}\right) + \mu_m + \nu_t = \bar{x} \tag{2}$$

According to (2), the number of employees in the metropolitan area is determined by the relationship between wages, the cost of living, and local amenities. A change in airport size may affect employment either through a change in productivity and thereby wages, or through a change in amenities. In either case equilibrium is restored by the change in the cost of living that results from a the change in population. The distinction is that a change in productivity affects wages, whereas a change in amenities does not. By observing how wages change when airport size changes, it should therefore be possible to determine to what degree a measured effect on employment is due to productivity.

The concept of market access for local firms is represented by the measure of airport size $A_{m,t}$.[3] The main measure is the number of departing flights, which reflects the overall convenience of travel for a potential passenger as it combines the number of destinations with the frequency of schedules. The measures based on the numbers of seats and passengers account for possible differences that correlate with aircraft size. The 'air access' variable more directly represents market access as it weights the number of flights by the populations of the metropolitan areas served by the destination airports, but may be less relevant to the amenity value of airports.

I assume the functional forms $w(A) \equiv \kappa_w \ln(A)$, $g(A) \equiv \kappa_g \ln(A)$, and $c(N) \equiv \ln(N)$ for the respective functions.[4] The term $\bar{x}$ is set to zero, as it can be captured in the fixed effects μ_m and ν_t, the sizes of which are not ultimately of interest. Making these substitutions in (2) and rearranging yields an expression for the natural level of employment $N^{\star}_{m,t}$ in metropolitan area m at time t:

$$N^{\star}_{m,t} = e^{\mu_m + \nu_t} A^{\kappa}_{m,t} \tag{3}$$

[3]Market access of course depends on permanent factors such as physical geography, which are captured by first-differencing and the metropolitan-area-level fixed effects. Other types of infrastructure such as roads and railways are also likely to be important. However, changes in road and rail networks are not a problem for the estimation provided that they are not correlated with the changes in airport size explained by the instruments, which appears unlikely.

[4]Imposing specific functional forms is naturally restrictive, but these functions have the crucial feature of allowing for any sign and magnitude for the effects of airport size on productivity and amenities through the parameters κ_w and κ_g.

The term $\kappa \equiv \kappa_w + \kappa_g$ in (3) captures the combined effect of the productivity and amenity mechanisms. It would be difficult to isolate the two in the estimation without introducing control variables (such as wages) that would be endogenous or imposing an overly restrictive structure. The approach used here is simply to separately estimate the effects of airport size on employment, total output (GDP), and wages, then compare the sizes of the coefficients. An effect on wages or a larger effect on output than on employment would suggest that airport size has an effect on productivity. If the effect on output is practically the same as the effect on employment and wages are not affected, then the effect would appear to be the result of the amenity value.

2.2 Growth in the local economy

The actual level of employment in metropolitan area m at time t is denoted $N_{m,t}$. The level of employment changes according to the difference between the current level $N_{m,t}$ and the natural level $N^{\star}_{m,t}$ in (3) according to the following convergence condition:

$$N_{m,t+1} = N^{\star\lambda_1}_{m,t} N^{\star\lambda_2}_{m,t+1} N^{1-\lambda_1-\lambda_2}_{m,t} \tag{4}$$

The change in local employment between t and $t+1$ is influenced by the natural level of employment at all points in time over that period, but the levels at the endpoints are used as an approximation. Employment at time $t+1$ depends on employment in the previous period, so $1-\lambda_1-\lambda_2 > 0$, and converges towards the natural levels of employment, so $\lambda_1, \lambda_2 > 0$. The following substitutions simplify the algebra:

$$(\lambda_1 + \lambda_2)\,\mu_m \equiv \gamma_{2,m}$$

$$\lambda_1 \nu_t + \lambda_2 \nu_{t+1} \equiv \delta_{2,t}$$

$$\kappa \equiv -\frac{\alpha_2}{\beta_2}$$

$$\lambda_1 \equiv \frac{\beta_2}{\alpha_2}\theta - \beta_2$$

$$\lambda_2 \equiv -\frac{\beta_2}{\alpha_2}\theta$$

Substituting (3) into (4) yields the following relationship between employment and airport size at times t and $t+1$:

$$\frac{N_{m,t+1}}{N_{m,t}} = e^{\gamma_{2,m}+\delta_{2,t}} A_{m,t}^{\alpha_2} N_{m,t}^{\beta_2} \left(\frac{A_{m,t+1}}{A_{m,t}}\right)^{\theta} \tag{5}$$

Taking logs of both sides of (5) and using the notation $a = \ln(A)$ and $n = \ln(N)$ for the log values:

$$n_{m,t+1} - n_{m,t} = \alpha_2 a_{m,t} + \beta_2 n_{m,t} + \theta\left[a_{m,t+1} - a_{m,t}\right] + \gamma_{2,m} + \delta_{2,t} \tag{6}$$

Equation (6) is the relationship between changes in local airport size and employment that I wish to estimate. The principal difficulty is that changes in local air traffic $a_{m,t+1} - a_{m,t}$ are likely influenced by variation in local employment $n_{m,t+1} - n_{m,t}$. I therefore instrument for the change in airport size using a set of variables that explain changes in local air traffic but are otherwise not affected by factors that correlate with changes in local employment. Further issues with the estimation of (6) are addressed below.

2.3 Structural changes in the air travel network

The instruments reflect changes in air traffic that are driven by overall changes in the air travel network. The instruments are expressed in terms of the growth in air traffic between t and $t+1$ were it to be determined entirely by these overall changes. The instrument for the level of air traffic at time $t+1$ is denoted $\hat{A}_{m,t+1}$. Given airport size $A_{m,t}$ and employment $N_{m,t}$ at time t and metropolitan-area- and time-specific factors $\gamma_{1,m}$ and $\delta_{1,t}$, the growth in air traffic explained by the instrument satisfies:

$$\frac{A_{m,t+1}}{A_{m,t}} = e^{\gamma_{1,m}+\delta_{1,t}} A_{m,t}^{\alpha_1} N_{m,t}^{\beta_1} \left(\frac{\hat{A}_{m,t+1}}{A_{m,t}}\right)^{\eta} \tag{7}$$

The controls for airport size and employment in (7) are intended to capture systematic differences in how airports are affected depending on airport size or the overall size of the metropolitan area.[5] Taking logs of both sides of (7) and again using $a = \ln(A)$ and $n = \ln(N)$ for the log values:

$$a_{m,t+1} - a_{m,t} = \alpha_1 a_{m,t} + \beta_1 n_{m,t} + \eta \left[\hat{a}_{m,t+1} - a_{m,t}\right] + \gamma_{1,m} + \delta_{1,t} \tag{8}$$

2.4 Estimation equations

The system of equations I estimate is derived from (6) and (8):

$$a_{m,t+1} - a_{m,t} = \alpha_1 a_{m,t} + \beta_1 n_{m,t} + \eta \left[\hat{a}_{m,t+1} - a_{m,t}\right] + \gamma_{1,m} + \delta_{1,t} + \varepsilon_{1,m,t} \tag{9}$$

$$n_{m,t+1} - n_{m,t} = \alpha_2 a_{m,t} + \beta_2 n_{m,t} + \theta \left[a_{m,t+1} - a_{m,t}\right] + \gamma_{2,m} + \delta_{2,t} + \varepsilon_{2,m,t} \tag{10}$$

For the system of equations (9) and (10) to be identified, the following conditions must be satisfied:

$$\eta \neq 0 \tag{11}$$

$$Cov\left(\hat{a}_{m,t+1} - a_{m,t}, \varepsilon_{2,m,t}\right) = 0 \tag{12}$$

Condition (11) is the relevance condition, which requires that the instruments explain a significant amount of the variation in airport sizes, conditional on the controls. This condition is tested statistically as part of the estimation.

Condition (12) is the exogeneity condition or exclusion restriction. It requires that the instrument affects changes in employment only through changes in airport size. While there is no statistical test for the exclusion restriction, I present three arguments in support of it. Firstly, in the description of how the instruments are calculated I detail why it is reasonable to believe that the condition holds. Secondly, I run overidentification tests that demonstrate that the second-stage residuals are indeed uncorrelated with the overidentifying instruments under the assumption that one of the instruments is valid. Thirdly, the tests of the effects of airports on employment by location within the metropolitan area serve as evidence in support of the airport affecting local

[5] As an example, airports depreciate meaning that it is costly to maintain them at their existing levels of capacity, so airports that are large relative to the communities they serve may therefore tend to decrease in size. Then again, increasing returns to scale in airport operation may lead to more rapid growth for larger airports.

employment rather than the reverse.

An additional concern with the estimation of (9) and (10) arises from the use of the control variables. The controls for $a_{m,t}$ and $n_{m,t}$ are included to account for systematic differences in airport and employment growth that correlate with airport and metropolitan-area size. The problem is that if the estimates of α_2 or β_2 are biased, then the coefficient on the change in airport size θ would also be biased. It is therefore not clear a priori whether it is good to include these controls. However, in Appendix D the main results are reproduced with and without each of the controls and the estimate of θ is practically identical in each case, mitigating the concern. A number of additional issues with the estimation are addressed in the robustness checks.

3 Data

The dataset used for the analysis is an annual panel of US air traffic, employment, and a range of other variables that reflect economic growth. The variables are assembled from a number of different sources. The panel covers the period from 1990 to 2012 and the variables are aggregated by Core Based Statistical Area (CBSA). The CBSAs are defined by the Office of Management and Budget as sets of counties, where each represents an urban core and the surrounding areas with which it is integrated by commuting. The December 2009 CBSA definitions are used.

The sample is limited to the contiguous United States – the District of Columbia and all states except for Alaska and Hawaii. The sample includes only airports that hosted at least 2,500 departing passengers – the threshold for a *Commercial Service Airport* according to the Federal Aviation Administration (FAA) – in all years from 1990 to 2013.[6] CBSAs with no such airports are excluded. This leaves 184 CBSAs and a total of 201 airports. Figure 1 presents a map of the CBSAs and airports in the sample and Table 1 presents the main variables in the dataset.

[6]Denver International Airport opened in 1995 and Austin–Bergstrom International Airport opened in 1999 as replacements for the main airports serving those cities. In each case the former airport was closed and its airport code was reassigned to the new airport. These airports are included in the sample and treated as continuously-operating airports: one (DEN) in the Denver-Aurora-Broomfield, CO CBSA and one (AUS) in the Austin-Round Rock-San Marcos, TX CBSA.

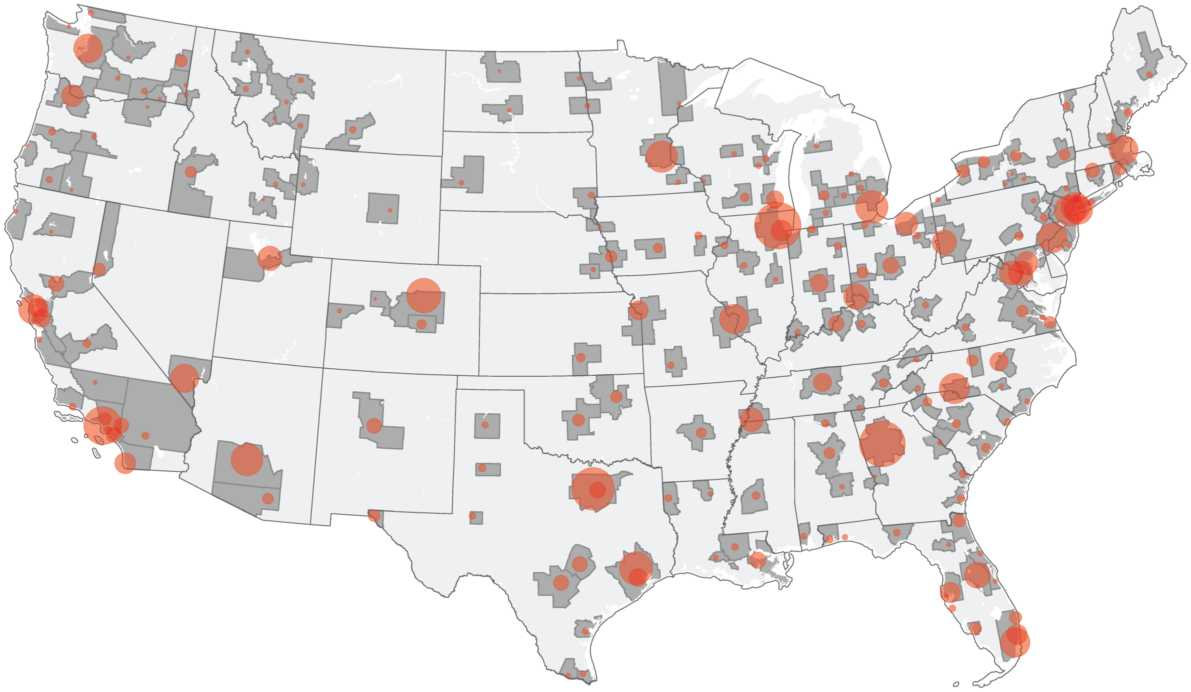

Figure 1: Map of the CBSAs and airports in the sample. The shaded areas of land represent the CBSAs. The shaded circles represent the airports, with the diameter of each circle proportional to the aggregate number of flights between 1990 and 2013.

	Mean	Std. dev.	Minimum	Maximum
Population	1,071,749	1,998,834	14,786	19,166,456
Number of employees	437,565	823,646	5,442	7,737,401
Mean wage ($'000)	30.17	8.44	13.15	90.50
Personal income per capita ($'000)	28.53	8.79	9.28	111.19
Number of firms	27,193	53,030	791	541,255
Gross domestic product (GDP) ($'bn)	44.26	100.15	0.21	1,323.43
Number of airports	1.09	0.44	1	5
Number of departing flights	43,639	86,136	146	652,164
Number of seats on departing flights	4,892,740	10,646,581	9,059	74,042,530
Number of departing passengers	3,349,586	7,486,481	3,998	56,381,774

Note: 4,232 observations of each variable, in a balanced panel of 184 CBSAs

Table 1: Summary statistics for the main variables in the data.

The air traffic levels are from the T-100 segment data compiled by the US Bureau of Transportation Statistics (BTS). The principal measure used for airport size is the number of passenger flights that depart from airports within the CBSA. This variable measures the physical amount of infrastructure indirectly and represents the practical convenience of the airport for a passenger, as it is a product of the number of destinations and the frequency of flights to those destinations. Nevertheless, the number of flights correlates with basic measures of physical airport size, as shown in Sheard (2014). The decision to measure airport size with air traffic is also motivated by the lack of detailed information about the physical features of an airport, the difficulty of quantifying these features, and the greater relevance of air traffic to the construction of the instrument.

Three alternative measures of airport size are also used: the number of seats on departing flights, the number of departing passengers, and a measure of 'air access'. The air access variable sums the number of flights to each destination airport weighted by the populations of the metropolitan area that they serve. Domestic and international flights are included, so the metropolitan-area populations are from different sources. For domestic destinations, the CBSA population figures from the US Census are used. For destinations in Canada, the figures for census metropolitan area (CMA) and census agglomeration (CA) populations from Statistics Canada are used. For other countries, the data are from the UN World Urbanization Prospects, which includes metropolitan areas with populations of 300,000 or more and the capital cities of sovereign states. Destinations that do not meet the respective definition are not included in the measure.

The main variables used to reflect economic growth are employment and GDP. The employment data are from the County Business Patterns, which state the number of employees in the week including the 12th of March in each year by county. These are aggregated to the CBSA level using the 2009 definitions. The GDP measure is based on the annual state-level estimates published by the Bureau of Economic Analysis. These are apportioned to the counties according to the contemporary shares of aggregate payroll in the County Business Patterns, then aggregated by CBSA.

The effects of airports on a number of other outcome variables are estimated. The annual population and personal income per capita are from the USA Counties database. The number of firms, aggregate payroll, and mean wage are from the County Business Patterns. The overall employment rate is simply the number of employees divided by the total population. The numbers of new housing unit authorizations are from the USA Counties database and the house price index is from the Federal Housing Finance Agency.

3.1 Instruments

The instruments I use for changes in air traffic are related to that proposed by Bartik (1991) for local economic growth. The Bartik instrument is calculated by taking the employment shares for the industries in each area, then assuming that employment in each industry grows at its national rate of growth. The result is a variable that reflects the changes in employment that are attributable to changes in overall industry-level resources and productivity, but is unrelated to changes in factors that are specific to the local area.

The instruments used in this paper are based on similar principles. Five instruments are constructed using the following categories for air traffic: the airline that operates the flight, the aircraft model, an aircraft-type classification based on the engine type and the number of seats in the aircraft, a set of ranges for the number of seats in the aircraft, and a set of ranges for the distance of the flight. Lists of the variables in each category are presented in Appendix A. Two of the instrument categories – the number of seats and the distance flown – are continuous variables of flight characteristics. Summary statistics for the distributions of these variables are given in Table 2.

				Percentile					
	Mean	Std. dev.	Minimum	5%	25%	50%	75%	95%	Maximum
Number of seats	117.5	63.4	1	30	50	132	143	226	490
Distance (miles)	816.7	955.1	9.0	118.9	279.7	523.8	968.9	2,464.1	10,274.0

Note: 196,803,699 observations, representing individual flights over the period from 1990 to 2012

Table 2: Summary statistics for the numbers of seats and the distance by flight.

The instruments are constructed as follows. Consider the 'airline' category as an example. I first observe the air traffic by airline in each CBSA at the start of a given period. I then find each airline's overall growth rate over the period from data on all flights originating or terminating in the contiguous US. Finally, I calculate how much traffic each CBSA would host at the end of the period if each airline increased its local traffic at its overall growth rate.

The main measure of airport size used is the number of departing flights. When the number of seats or the number of passengers is used in the estimation, the instruments are calculated from local levels and overall growth rates of the respective measure. With the air access measure, the instrument is calculated by applying the overall growth rates to the number of flights on each route.

The following hypothetical example illustrates how the instruments are calculated. Table 3 represents a single metropolitan area m that hosts airlines A, B, and C at time t. Between times t and $t+1$, airline A ceases to operate and airline D begins operating. The overall rates of growth in the airlines' operations – the number of flights operated in the US at time $t+1$ divided by the number operated at time t – are shown in the first column. The instrument is calculated by multiplying these rates by the numbers of flights at time t.

		In metropolitan area m		
			Traffic at time t+1	
Airline	Overall growth rate t to t+1	Traffic at time t	Actual	Instrument
A	0	20	0	0
B	1.1	30	0	33
C	1.3	50	55	65
D	n/a	–	15	–
Total		100	70	98

Table 3: Example of calculation of the instrument for growth in air traffic between times t and $t+1$ at a hypothetical metropolitan area m.

Airline A's operations drop to zero so its contribution to the instrument is zero. Airline B stops operating at m but grows overall so its contribution to the instrument reflects a positive rate of growth. Airline C's traffic grows less quickly in m than it does overall, so the instrument value is larger than the actual level of traffic at time $t+1$. Airline D has operates in m at time $t+1$ but had no traffic there at t and therefore is not included in the instrument value at time $t+1$.

The traffic at a given airport naturally contributes to the overall national level of traffic. Changes in air traffic in a given CBSA are therefore reflected in the instrument for that CBSA, which may threaten the exclusion restriction. To minimize this possibility I calculate the overall growth rate separately for each CBSA, excluding flights to and from that CBSA in the calculation. Figure 2 illustrates an example of a network with the flights to and from a specific CBSA excluded.

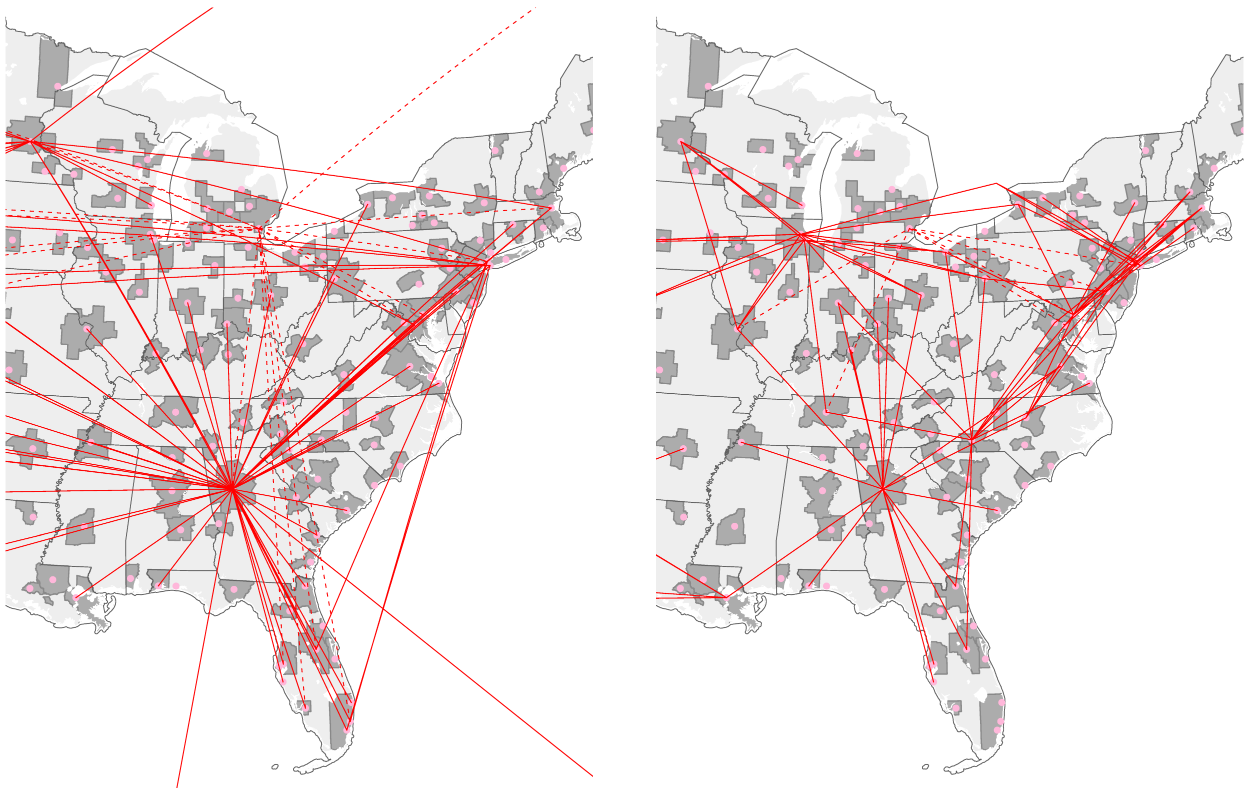

Figure 2: Networks of flights for two example categories. The map on the left represents routes (airport pairs) operated by Delta Air Lines with an average of at least 1,000 daily passengers in 2010. The map on the right represents routes between 250 and 500 miles in length with at least 1,000 daily passengers in 2010. The dots represent airports in the sample and the lines represent the routes. To calculate the overall growth rate that is applied to a CBSA the routes to and from that CBSA are excluded. To illustrate this with an example, the routes with an endpoint in the Detroit-Warren-Livonia CBSA are represented by dashed lines.

The principle underlying these instruments is that growth rates in the categories are orthogonal to CBSA-specific factors. The part of the variation in local air traffic that is determined by overall growth in an airline's traffic should not be related to changes in local conditions, in particular when traffic from the local area is excluded from the calculation of the overall growth rate applied to each observation. Rather, an airline's overall level of traffic should influence its traffic at individual airports through determinants of its overall demand and productivity such as innovations in its methods of operation, marketing, and labor relations. When the demand or productivity of an airline increases, it tends to increase traffic at airports where it already operates as it has gates, slots, hangar space, and employees based at those facilities.

Similar reasoning applies to the three categories for the type of aircraft: the model, class, and number of seats. The total amount of traffic operated using a particular type of aircraft influences traffic at airports that already host operations of that aircraft, as these airports have facilities such as runways, aprons, hangars, and terminals capable of handling them. If a new type of aircraft is introduced or additional units are produced, it will tend to be used at airports that already host similar aircraft. Furthermore, the variation in an airport's traffic explained by overall changes in use of the aircraft it hosts could not be influenced by local factors such as employment or demography. The instrument based on distance categories is intended to reflect overall changes in aircraft technology and the methods of operating the air travel network, such as changes in the ranges of aircraft, the prevalence of short- and long-haul flights, and the routing of traffic through hubs.

For the number of seats or the distance of the flight, the changes in overall traffic driven by underlying factors should be continuous in the levels of those variables. That is, a change that makes it more practical to fly a given distance should also make it somewhat more practical to fly a slightly shorter or longer distance. It would also be possible to substitute between similar distances to some degree. At the same time, there are certain ranges with relatively few observations. To take advantage of the information in observations for similar numbers of seats or distances, the observed growth rates are smoothed over these categories for each CBSA and time span using the method described in Appendix B.

The essential qualities of an instrument are that it satisfy the relevance condition (11) and the exclusion restriction (12). The relevance condition (11) is straightforward to test statistically as it simply requires a significant relationship between the instrument and changes in airport sizes, given the controls, and all of these variables are known.[7] The results below demonstrate that each of the instruments exceeds a reasonable threshold for the relevance condition to be satisfied.

The exclusion restriction requires that an instrument only be related to changes in employment or the alternative outcome variable through its effect on the level of air traffic. This condition would be violated either if the instrument affected other factors that in turn affected the outcome variable or if both the instrument and the outcome variable were affected by some unobserved factor. Both possibilities appear unlikely. Apart from the variation in airport sizes explained by the instrument, there is no clear channel through which the concentrations of certain airlines or aircraft

[7]The main results include all of the controls and fixed effects detailed in (9) and (10) in the estimation. However, the instruments are also strong when the controls for the levels of traffic and employment at the beginning of the period are excluded, and without the CBSA and year fixed effects they are substantially stronger, as shown in Appendix D.

at an airport could influence factors for local growth. There is a concern that a certain airline or type of aircraft may locate in places where stronger employment growth is anticipated, though the analysis in Appendix C demonstrates that the growth rate of an airline, aircraft class, or distance group is not correlated with the mean levels of air traffic and employment in the metropolitan areas that it serves. Furthermore, the fact that the variation in the instruments is driven by overall growth rates eliminates the possibility of correlation with exogenous changes in other local factors that affect employment.

4 Estimation

The results from the ordinary least squares (OLS) estimation of (10) are presented in Table 4. This technique reflects how changes in airport size are correlated with changes in employment and GDP, but as it does not deal with the endogeneity issues the results are not reliable estimates of a causal relationship. Panel A of Table 4 displays the results for the relationship between airport size and employment; Panel B displays the results for airport size and GDP. Each of the specifications exhibits a strong positive correlation between changes in airport size and changes in employment and GDP.

Airport-size measure	(1) OLS Flights	(2) OLS Flights	(3) OLS Flights	(4) OLS Flights	(5) OLS Flights	(6) OLS Flights	(7) OLS Seats	(8) OLS Pass.	(9) OLS Air access
Panel A. Dependent variable: Change in log CBSA-level employment.									
$\ln(airpt_{m,t+1}) - \ln(airpt_{m,t})$	0.015^a	0.015^a	0.009^a	0.009^a	0.008^a	0.010^a	0.011^a	0.013^a	0.006^a
	(0.003)	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)	(0.002)
$\ln(airpt_{m,t})$					−0.002	0.002	0.002	0.002	0.001
					(0.002)	(0.002)	(0.002)	(0.002)	(0.001)
$\ln(emp_{m,t})$						−0.091a	−0.091a	−0.091a	−0.091a
						(0.007)	(0.007)	(0.007)	(0.007)
R^2	0.01	0.09	0.39	0.47	0.47	0.51	0.51	0.51	0.51
Panel B. Dependent variable: Change in log CBSA-level GDP.									
$\ln(airpt_{m,t+1}) - \ln(airpt_{m,t})$	0.026^a	0.026^a	0.015^a	0.015^a	0.013^a	0.016^a	0.014^a	0.020^a	0.010^a
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)	(0.005)	(0.003)
$\ln(airpt_{m,t})$					−0.003	0.002	−0.001	0.001	0.003
					(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
$\ln(gdp_{m,t})$						−0.079a	−0.078a	−0.078a	−0.080a
						(0.008)	(0.008)	(0.008)	(0.008)
R^2	0.02	0.10	0.20	0.29	0.29	0.32	0.32	0.32	0.32
CBSA fixed effects		Y		Y	Y	Y	Y	Y	Y
Year fixed effects			Y	Y	Y	Y	Y	Y	Y

Note: 4,048 observations for each regression, representing 184 CBSAs; robust standard errors in parentheses; a, b, c denote significance at 1%, 5%, 10%

Table 4: OLS estimation of the relationships between airport size and employment and GDP at the CBSA level.

Columns 1 through 6 of Table 4 use different arrays of the independent variables and fixed effects included in equation (10) to demonstrate how the estimation is affected by the inclusion of these variables. Column 1 shows the estimates without any controls. Column 2 uses CBSA fixed effects, which make little difference to the coefficient on the change in airport size. Column 3 uses year fixed effects, which decrease the magnitude of the coefficient and so apparently capture some of the correlation between changes in airport size and employment. Column 4 includes both CBSA and year fixed effects.

Column 5 adds a control for log airport size at the beginning of the year. If there is a relationship between airport size and employment, then initial airport size could be expected to be correlated with changes in employment. However, the coefficients on the initial airport size are insignificant and their inclusion makes little difference to the R^2 or the coefficients on the change in airport size. A possible explanation is that air traffic rapidly adjusts to match demand while local employment rapidly adjusts to changes in the availability of flights. Another possibility is that the differences in airport size driven by historical factors and geography influence current employment growth, but that as these apply across all years of the panel they are captured in the CBSA fixed effects.

Column 6 adds the log levels of employment and GDP at the start of the period. The significant negative sign on the coefficient indicates that a CBSA that is initially larger tends to have a lower rate of growth. This is my preferred specification: including all variables in (10) with airport size measured as the number of flights.

Columns 7 and 8 estimate (10) using the number of seats on departing flights and the number of departing passengers, respectively, as the measure of airport size. Column 9 uses the air access measure, which weights the number of flights by the populations of destination metropolitan areas. The coefficients on airport size measured using these variants are positive and similar in magnitude to those using the number of flights.

The OLS results in Table 4 demonstrate a clear, positive relationship between airport size and both employment and GDP within a metropolitan area. Whether or not air traffic affects employment or GDP, there is a positive correlation between changes in the two variables. To measure the causal effect of air traffic on local employment and GDP, I estimate the system (9) and (10) using two-stage least squares (TSLS) with the instruments detailed above.

The first stage of the estimation establishes the causal relationship between the instruments and the variation in airport size using (9). The results from the first stage are displayed in Table 5.[8] All columns use the full specification of (9) but apply different sets of instruments. The inclusion of the controls for initial airport size and employment is not crucial as the results are similar whether or not these are included, as demonstrated in Appendix D.

[8]The estimates in Table 5 use employment as the independent variable for the local economic outcome, though GDP is also used in the two-stage estimation. The results using GDP are not shown as they are nearly identical to those in Table 5.

Airport-size measure	(1) OLS Flights	(2) OLS Flights	(3) OLS Flights	(4) OLS Flights	(5) OLS Flights	(6) OLS Flights	(7) OLS Flights	(8) OLS Flights	(9) OLS Flights
‘Airline’ instrument	0.231^a					0.211^a	0.216^a		0.209^a
	(0.045)					(0.042)	(0.043)		(0.042)
‘Aircraft model’ instrument		0.144^a							
		(0.051)							
‘Aircraft class’ instrument			0.526^a			0.429^a		0.403^a	0.335^a
			(0.076)			(0.071)		(0.065)	(0.063)
‘Number of seats’ instrument				0.801^a					
				(0.141)					
‘Distance’ instrument					0.993^a		0.792^a	0.484^c	0.376
					(0.247)		(0.232)	(0.266)	(0.251)
$\ln(airpt_{m,t})$	-0.209^a	-0.208^a	-0.222^a	-0.222^a	-0.208^a	-0.217^a	-0.206^a	-0.218^a	-0.214^a
	(0.020)	(0.020)	(0.020)	(0.020)	(0.020)	(0.020)	(0.020)	(0.020)	(0.020)
$\ln(emp_{m,t})$	0.164^a	0.153^a	0.179^a	0.187^a	0.167^a	0.179^a	0.169^a	0.178^a	0.179^a
	(0.046)	(0.046)	(0.047)	(0.047)	(0.047)	(0.046)	(0.046)	(0.047)	(0.046)
R^2	0.35	0.30	0.32	0.32	0.31	0.37	0.36	0.32	0.37
F-stat. on the instrument(s)	26.66	8.06	47.71	32.21	16.21	36.62	20.04	29.70	29.67

Note: 4,048 observations for each regression, representing 184 CBSAs; robust standard errors in parentheses; a, b, c denote significance at 1%, 5%, 10%; all regressions include CBSA and year fixed effects

Table 5: First-stage estimation of the relationships between the instruments and airport size at the CBSA level.

The results in Table 5 demonstrate that the instruments explain a significant amount of the variation in airport sizes. The ‘airline’ instrument is positive and the F-statistic indicates that it is comfortably large enough to be considered a relevant instrument for airport size.[9] The ‘aircraft model’ instrument has a positive coefficient but is not strong enough to put the relevance of the instrument beyond doubt. I suspect this instrument is weaker because it is simply too narrow a classification of aircraft type.[10] In any case, the instrument constructed using the broader ‘aircraft class’ classification is positive and strong. The ‘number of seats’ instrument also reflects the type of aircraft and is strongly positive. However, I prefer the ‘aircraft class’ instrument because the information contained in the engine-type classification makes it somewhat richer. The ‘distance’ instrument is also positive and meets a reasonable threshold to be deemed relevant.

[9] Staiger and Stock (1997) established the customary threshold of 10 for the first-stage F-statistic. Stock and Yogo (2005) calculated critical values under the assumption of independent and identically distributed errors. With a maximal size of 15% – meaning that a Wald test of $\beta = \beta_0$ with a 5% confidence level rejects the null no more than 15% of the time – the critical values are 8.96 in the case of one instrument and one endogenous regressor and 12.83 when there are three instruments and one endogenous regressor. With a maximal size of 10% the critical values are 16.38 for one instrument and one endogenous regressor and 22.30 for three instruments and one endogenous regressor.

[10] By its nature the instrument is weak for sufficiently narrow or broad categories. The narrower the category, the fewer observations there are outside of the CBSA to calculate the overall growth rate, and the more the traffic reflects idiosyncratic factors in other places rather than overall factors for the category. The broader the category, the closer the overall growth rate is to the aggregate growth in traffic for the entire US, which is captured by the year fixed effects.

The analysis continues with the instruments constructed using the ‘airline’, ‘aircraft class’, and ‘distance’ categories. These instruments are each clearly relevant and their classifications are conceptually diverse: the first reflects the airline operating the flights, the second reflects the type of aircraft, and the third reflects the way that the air travel network is arranged.

Columns 6, 7, and 8 of Table 5 use pairs of the three selected instruments and column 9 uses all three. For all combinations the F-statistics are large and the coefficients on the instruments are positive in magnitude and generally significant. All three of these instruments therefore appear to contribute to the variation in airport sizes explained by the model.

Table 6 presents the results from the second stage of the TSLS estimation. Panel A represents the effect of airport size on local employment and Panel B represents the effect of airport size on local GDP. Columns 1 through 4 use the standard airport-size measure of the number of departing flights and different combinations of the three preferred instruments. Columns 5 and 6 use the number of seats on departing flights and the number of departing passengers, respectively, as the measures of airport size. Column 7 uses the air access measure for airport size.

To evaluate the relevance of the instruments, I run Kleinbergen-Paap *rk* Wald tests. To test the overidentifying restrictions in regressions that use more than one instrument, I run Sargan-Hansen tests. To determine whether the differences between the OLS and TSLS coefficients are statistically different, I run Hausman tests. The F-statistics from the Wald tests and the p-values from the Sargan-Hansen and Hausman tests are displayed at the bottom of each panel.

Airport-size measure	(1) TSLS Flights	(2) TSLS Flights	(3) TSLS Flights	(4) TSLS Flights	(5) TSLS Seats	(6) TSLS Pass.	(7) TSLS Air access
Panel A. Dependent variable: Change in log CBSA-level employment.							
$\ln(airpt_{m,t+1}) - \ln(airpt_{m,t})$	0.016^b	0.029^b	0.024^b	0.020^a	0.021^b	0.026^b	0.014^a
	(0.008)	(0.011)	(0.012)	(0.007)	(0.010)	(0.012)	(0.005)
$\ln(airpt_{m,t})$	0.003	0.005^c	0.004	0.004^c	0.004	0.004	0.002
	(0.002)	(0.003)	(0.003)	(0.002)	(0.003)	(0.003)	(0.002)
$\ln(emp_{m,t})$	-0.092^a	-0.094^a	-0.093^a	-0.093^a	-0.093^a	-0.092^a	-0.093^a
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
First-stage statistic	26.66	47.71	16.21	29.67	21.25	20.62	23.99
Overid. p-value				0.63	0.21	0.52	0.12
Hausman test p-value	0.47	0.09	0.22	0.13	0.31	0.19	0.23
Panel B. Dependent variable: Change in log CBSA-level GDP.							
$\ln(airpt_{m,t+1}) - \ln(airpt_{m,t})$	0.034^b	0.030^c	0.032^c	0.033^a	0.034^c	0.040^c	0.019^a
	(0.015)	(0.015)	(0.016)	(0.011)	(0.018)	(0.020)	(0.007)
$\ln(airpt_{m,t})$	0.005	0.005	0.005	0.005	0.003	0.005	0.005^c
	(0.004)	(0.004)	(0.004)	(0.003)	(0.004)	(0.004)	(0.002)
$\ln(gdp_{m,t})$	-0.082^a	-0.081^a	-0.081^a	-0.082^a	-0.080^a	-0.079^a	-0.082^a
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
First-stage statistic	26.41	47.07	16.00	29.27	20.78	20.34	23.43
Overid. p-value				0.99	0.71	0.92	0.64
Hausman test p-value	0.22	0.34	0.30	0.10	0.30	0.24	0.22
‘Airline’ instrument	Y			Y	Y	Y	Y
‘Aircraft class’ instrument		Y		Y	Y	Y	Y
‘Distance’ instrument			Y	Y	Y	Y	Y

Note: 4,048 observations for each regression, representing 184 CBSAs; robust standard errors in parentheses; a, b, c denote significance at 1%, 5%, 10%; all regressions include CBSA and year fixed effects

Table 6: Second-stage estimation of the effects of airport size on employment and GDP at the CBSA level.

The TSLS results in Table 6 indicate that airport size has a positive effect on employment and on GDP. The effects are positive for all instruments and for each measure of airport size. The magnitude of the effects vary with the choice of instrument but are around 0.02 for employment and 0.035 for GDP when the number of flights is used as the measure of airport size. The coefficient for GDP being larger than that for the number of employees is consistent with airports having a positive effect on output per worker. The coefficients are similar when airport size is measured as the number of seats and slightly larger for the number of departing passengers.

The effect on employment is smaller when airport size is measured as ‘air access’ rather than the number of flights. Recall that these measures differ only in that the former weights the number of flights by the populations of the destination metropolitan areas. The difference between the coefficients suggests that the sizes of the destinations accessed by additional flights is not of primary importance. This could be an indication of the amenity value of airports.

An increase in air traffic has a direct effect on employment, as some number of cabin and ground crew and other workers are required to operate the flights. It is therefore possible to express the size of the effect in terms of the ratio of jobs created at and outside of the airport. According to the figures published by the BTS, approximately 0.55% of total employment in US CBSAs in 2010 was in the air travel industry. An elasticity of 0.02 therefore implies a multiplier of around 3.9, meaning that in a metropolitan area with an average-sized airport, for every job created at the airport there are approximately three jobs created elsewhere in the CBSA in other industries.

The TSLS coefficients on the change in airport size are larger in magnitude than the OLS coefficients for all instruments and for both employment and GDP. The results from the Hausman tests show that the differences are generally not significant. Nonetheless, the possibility of the TSLS coefficients being larger than the OLS coefficients deserves some explanation, as it would suggest negatively-biased OLS coefficients, the opposite of what would be expected if employment has a positive effect on airport size. A possible explanation is that the coefficients could reflect a particular type of treatment effect, as the variation in airport sizes explained by the instrument is more effective in spurring the local economy that other sources of variation.

The first-stage statistics indicate that all of the instruments satisfy a reasonable threshold for them to be deemed relevant, as demonstrated in the first-stage results presented above. The overidentification tests indicate no rejection in any of the regressions and therefore do not suggest that the overidentifying restrictions are invalid.

In the remainder of this section I estimate a number of alternative specifications of the relationship between airport size and local economic growth, estimate the effects on industry-level employment, and then study how employment is affected within a CBSA by proximity to the airport. Finally, I present the results from a number of robustness checks. In Appendix E I reproduce the main results using a GMM estimator.

4.1 Effects by length of delay

The estimates presented above all used periods of one year for the changes in airport size, the instrumental variables, and employment and GDP. It is possible that the size of the effect on the local economy may depend on the amount of time that elapses. To investigate how the effects on employment develop over time, I estimate the system of equations (9) and (10) using delays for all growth variables of one to eight years. The series of intervals are non-overlapping, with the first beginning in 1990 for each length of delay, so the number of observations decreases with the length of delay. The results are presented in Table 7. The OLS estimates are presented in Panel A and the TSLS estimates are presented in Panel B.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Delay in years (s)	1	2	3	4	5	6	7	8
Panel A. OLS estimation.								
$\ln(airpt_{m,t+s}) - \ln(airpt_{m,t})$	0.010^a	0.019^a	0.021^a	0.027^a	0.019^b	0.024^b	0.029^a	0.059^a
	(0.002)	(0.004)	(0.004)	(0.007)	(0.008)	(0.010)	(0.008)	(0.015)
$\ln(airpt_{m,t})$	0.002	0.003	−0.001	0.007	−0.010	−0.013	0.002	0.044^c
	(0.002)	(0.003)	(0.005)	(0.008)	(0.011)	(0.012)	(0.014)	(0.022)
$\ln(emp_{m,t})$	-0.091^a	-0.185^a	-0.271^a	-0.371^a	-0.414^a	-0.384^a	-0.507^a	-0.535^a
	(0.007)	(0.013)	(0.022)	(0.031)	(0.035)	(0.045)	(0.040)	(0.067)
R^2	0.51	0.65	0.72	0.76	0.79	0.76	0.86	0.86
Panel B. TSLS estimation. Instrumental variable categories: airline, aircraft class, and distance.								
$\ln(airpt_{m,t+s}) - \ln(airpt_{m,t})$	0.020^a	0.025^a	0.026	0.007	0.040	0.014	−0.047	0.020
	(0.007)	(0.009)	(0.018)	(0.027)	(0.029)	(0.023)	(0.074)	(0.037)
$\ln(airpt_{m,t})$	0.004^c	0.006	0.002	−0.008	0.007	−0.022	−0.079	−0.010
	(0.002)	(0.005)	(0.012)	(0.021)	(0.025)	(0.022)	(0.078)	(0.051)
$\ln(emp_{m,t})$	-0.093^a	-0.187^a	-0.273^a	-0.365^a	-0.419^a	-0.380^a	-0.477^a	-0.526^a
	(0.007)	(0.014)	(0.022)	(0.031)	(0.036)	(0.045)	(0.050)	(0.068)
First-stage statistic	29.67	17.94	9.26	2.28	5.37	24.24	0.68	14.68
Overid. p-value	0.63	0.12	0.84	0.21	0.47	0.73	0.24	0.25
Hausman test p-value	0.13	0.66	0.83	0.26	0.36	0.57	0.18	0.16
Number of observations	4,048	2,024	1,288	920	736	552	552	368

Note: 184 CBSAs for each regression; robust standard errors in parentheses; a, b, c denote significance at 1%, 5%, 10%; number of departing flights used as the measure of airport size; all regressions include year and CBSA fixed effects

Table 7: Relationship between airport size and employment for a range of time delays.

The OLS results in Table 7 indicate that changes in airport size are correlated with changes in local employment and GDP for the full range of delays. Furthermore, the coefficients are increasing in magnitude with the length of the delay, suggesting that the correlation becomes stronger over time.

The TSLS results in Table 7 do not demonstrate a clear relationship between the length of the delay and the strength of the effect of airport size on employment or GDP. As the delays become longer and the samples thereby smaller, the standard errors on the first and second stages become larger. This reduces the F-statistic on the instruments and the significance of the coefficient on the change in airport size, but there is no clear trend in the magnitude of the coefficient. Furthermore, for the delays for which the instruments are strong, the differences between the coefficients fall within the bounds of one standard error.

4.2 Alternative measures of economic growth

The main results displayed in Table 4 use the number of employees and GDP as the measures of local economic growth. In this section I estimate the effects of airports on a range of other outcome variables, which either directly or indirectly reflect economic growth. Table 8 explores the effects of airports on the changes in seven such variables, each of which appears in log differences as the dependent variable in (10).

	(1) Number of firms	(2) Employ. rate	(3) Aggregate payroll	(4) Mean wage	(5) Pers. Inc. per capita	(6) New house approvals	(7) House prices
Panel A. OLS estimation.							
$\ln(airpt_{m,t+1}) - \ln(airpt_{m,t})$	0.007^{a}	0.006^{a}	0.014^{a}	0.005^{b}	0.005^{c}	0.060^{b}	0.023^{a}
	(0.001)	(0.002)	(0.003)	(0.002)	(0.003)	(0.024)	(0.006)
$\ln(airpt_{m,t})$	0.001^{c}	−0.002	0.001	0.002	−0.001	0.003	0.017^{b}
	(0.001)	(0.001)	(0.002)	(0.001)	(0.002)	(0.016)	(0.007)
$\ln(outcome_{m,t})$	-0.053^{a}	-0.128^{a}	-0.072^{a}	-0.156^{a}	-0.136^{a}	-0.276^{a}	-0.182^{a}
	(0.004)	(0.010)	(0.008)	(0.015)	(0.044)	(0.018)	(0.061)
R^2	0.63	0.49	0.50	0.26	0.42	0.43	0.46
Panel B. TSLS estimation. Instrumental variable categories: airline, aircraft class, and distance.							
$\ln(airpt_{m,t+1}) - \ln(airpt_{m,t})$	0.014^{a}	0.012^{b}	0.030^{a}	0.011^{b}	0.019^{a}	0.086^{c}	0.008
	(0.003)	(0.006)	(0.009)	(0.005)	(0.007)	(0.051)	(0.012)
$\ln(airpt_{m,t})$	0.003^{a}	−0.001	0.005^{c}	0.003^{b}	0.001	0.009	0.014^{b}
	(0.001)	(0.002)	(0.003)	(0.002)	(0.002)	(0.020)	(0.006)
$\ln(outcome_{m,t})$	-0.054^{a}	-0.129^{a}	-0.075^{a}	-0.158^{a}	-0.139^{a}	-0.277^{a}	-0.181^{a}
	(0.004)	(0.010)	(0.008)	(0.015)	(0.044)	(0.018)	(0.061)
First-stage statistic	28.85	29.02	29.51	28.65	28.54	26.25	20.97
Overid. p-value	0.25	0.96	0.41	0.65	0.41	0.96	0.09
Hausman test p-value	0.03	0.28	0.03	0.26	0.04	0.51	0.45
Number of observations	4,048	4,048	4,048	4,048	4,048	3,680	3,426
Number of CBSAs	184	184	184	184	184	184	156

Note: robust standard errors in parentheses; a, b, c denote significance at 1%, 5%, 10%; number of departing flights used for airport size; all regressions include year and CBSA fixed effects

Table 8: Relationships between airport size and various outcome variables.

The results presented in Table 4 indicate that changes in airport size have positive effects on measures of economic growth besides employment and GDP. Airport size has a positive effect on the number of firms in a metropolitan area, with a magnitude somewhat smaller than that for the effect on the number of employees. This suggests that both the number of firms and the mean number of employees per firm increase when the airport increases in size. The effect on the employment rate is positive and approximately half as large as the effect on the number of employees. This indicates that around half of the new jobs generated represent a net increase in employment for existing residents and half are taken up by migrants to the metropolitan area.

The effect of the airport on aggregate payroll is positive, larger in magnitude than the effect on employment, and similar to the effect on GDP. This suggests that airport size has a positive effect on income per employee, which is consistent with the measured effects on mean wages and personal income per capita.

The evidence of the effects on house construction and prices is ambiguous, though the samples are smaller for these variables. The coefficient for the number of new house approvals is positive in magnitude but only weakly significant, though this variable is only available up until 2010. The coefficient for the house price index is not significant, though this variable is available for a smaller number of CBSAs.

4.3 Industry-level employment

To better understand how airports affect local employment, this section estimates the effects on the levels of employment in different industries. The industry classification used by the US Census Bureau changed during the period of the data, from the Standard Industrial Classification (SIC) to the North American Industry Classification System (NAICS). It is therefore necessary use fairly broad definitions of industries and to apply an appropriate mapping between the SIC and NAICS definitions. Hence the industries observed are *construction*, *manufacturing*, *wholesale and retail trade*, *transportation and utilities*, and *services*. The mapping between SIC and NAICS codes is detailed in Appendix F. The results from the estimation are presented in Table 9.

Industry	(1) Construction	(2) Manufacturing	(3) Wholesale & ret. trade	(4) Transport. & utilities	(5) Services
Panel A. OLS estimation.					
$\ln(airpt_{m,t+1}) - \ln(airpt_{m,t})$	0.043^{a}	0.001	−0.011	0.016	0.028^{a}
	(0.007)	(0.007)	(0.010)	(0.011)	(0.010)
$\ln(airpt_{m,t})$	0.011^{b}	-0.009^{c}	0.006	0.013^{c}	0.008^{b}
	(0.005)	(0.005)	(0.005)	(0.006)	(0.003)
$\ln(emp_{m,t})$	-0.193^{a}	-0.139^{a}	-0.168^{a}	-0.154^{a}	-0.225^{a}
	(0.012)	(0.030)	(0.043)	(0.030)	(0.046)
R^2	0.44	0.31	0.93	0.55	0.71
Panel B. TSLS estimation. Instrumental variable categories: airline, aircraft class, and distance.					
$\ln(airpt_{m,t+1}) - \ln(airpt_{m,t})$	0.052^{b}	0.012	−0.007	0.027	0.038^{b}
	(0.022)	(0.021)	(0.026)	(0.036)	(0.017)
$\ln(airpt_{m,t})$	0.013^{c}	−0.007	0.007	0.015	0.010^{b}
	(0.007)	(0.006)	(0.007)	(0.010)	(0.005)
$\ln(emp_{m,t})$	-0.194^{a}	-0.142^{a}	-0.167^{a}	-0.156^{a}	-0.227^{a}
	(0.012)	(0.030)	(0.041)	(0.030)	(0.046)
First-stage statistic	29.10	28.79	29.23	28.93	28.50
Overid. p-value	0.48	0.15	0.60	0.32	0.26
Hausman test p-value	0.64	0.31	0.47	0.68	0.34
Number of observations	4,048	4,048	4,048	4,046	4,045

Note: 184 CBSAs for each regression; robust standard errors in parentheses; a, b, c denote significance at 1%, 5%, 10%; number of departing flights used as the measure of airport size; all regressions include CBSA and year fixed effects

Table 9: Relationships between airport size and employment in specific industries.

The results in Table 9 indicate that the measured effect of airport size on employment is driven by changes in employment in certain industries. There is no measurable effect of airports on employment in manufacturing, wholesale and retail trade, or transportation and utilities. However, there are positive effects on construction and services, with magnitudes larger than that for the effect on overall employment.

Of the industry groups included inthe analysis, the new jobs created by an increase in airport size therefore appear to be predominantly in services and construction. The effect on services employment is intuitive as this industry involves many personal interactions and is more likely to benefit from better possibilities for air travel. The effect on construction is more difficult to explain but could in part be a direct effect of the work required to expand an airport and related infrastructure. Employment in transportation and utilities may be expected to increase when air traffic increases, again through a direct effect, but although the coefficient is positive in magnitude it is not significant. The other industries that are not affected – manufacturing and wholesale and retail trade – have less intuitive connection with air travel. These results are consistent with the findings of Sheard (2014) that airport size has a positive effect on tradable services but not on manufacturing.

4.4 Proximity to the airport within the metropolitan area

The results presented above indicate that airport size has a positive effect on employment and production in a metropolitan area. In this section I test whether the effects differ within the metropolitan area depending on proximity to the airport. In designing policy it is important to understand how the local airport affects the local economy in its entirety. However, it is also valuable to understand how the effects differ by neighborhood. If certain parts of the metropolitan area are affected more by a change in airport size, then it would be understood that airport improvements would have greater effects in those neighborhoods. Airport spending could therefore be considered as an option for developing those neighborhoods.

An additional reason to test the effects on neighborhoods by proximity to the airport is that it provides an additional test of the validity of the exclusion restriction. Demand for air travel should come from residents of the entire metropolitan area, in particular if there is no other large airport nearby.[11] Therefore, increases in employment in neighborhoods far from the airport should be associated with an increase in air traffic. However, firms that rely on air travel would value proximity to the airport and are more likely to choose locate relatively close to it. If the exclusion restriction is violated, then one symptom could be that the effects are similarly strong across the metropolitan area.

The exercise carried out here is to divide up the CBSAs by compass direction from the CBSA midpoint and then test the effects on employment in segments delimited by the direction to them relative to the direction to the airport. The midpoint of each CBSA is defined as the center of the downtown employment cluster of the city specified as the 'core' of the CBSA.[12] It would be prob-

[11]Brueckner, Lee and Singer (2014) demonstrate that the appropriate level of aggregation for passenger air travel markets is the city, rather than the airport.

[12]Lacking a reliable criterion for identifying the 'central business district' of a metropolitan area directly from data, the CBSA midpoints were chosen by hand. The primary source of information for this exercise was the maps, satellite photos, and street-level photos on Google Maps. For each CBSA, the midpoint was chosen as the center of the densest area of business activity – in most cases the tallest cluster of office buildings – in the 'core' of the CBSA. By definition,

lematic to determine the appropriate direction to the airport in CBSAs with multiple commercial airports, so only CBSAs with a single airport in the main sample are used. The Denver-Aurora-Broomfield, CO and Austin-Round Rock-San Marcos, TX CBSAs are also excluded as their airports were moved to new locations during the period.[13] This leaves 171 CBSAs. As this exercise requires employment data at a low degree of geographical aggregation, the ZIP Code-level information from the County Business Patterns is used. The earliest available year for this dataset is 1994.

The first test divides up the employment data in each CBSA along a single axis through the CBSA midpoint and at an angle of 90° from the direction of the airport. The second test divides up the data into three groups, along axes at 60° and 120° from the direction of the airport. Figure 3 illustrates how these areas are defined using the Minneapolis-St. Paul-Bloomington, MN-WI CBSA as an example.

the 'core' of a CBSA is its largest urban cluster. This is indicated by the name of the CBSA, which lists the urban clusters within a CBSA in decreasing order of size. For example, the CBSA mapped in Figure 3 is named *Minneapolis-St. Paul-Bloomington, MN-WI*, indicating that the 'core' of the CBSA is Minneapolis, MN. Where a CBSA has more than one urban cluster the largest of these is used, rather than choosing an intermediate location that may well be sparsely populated or in a body of water.

[13] As mentioned above, in each of these cases the main airport that served the metropolitan area was replaced with a newly-built facility, which took over the operations and the airport code of the old airport.

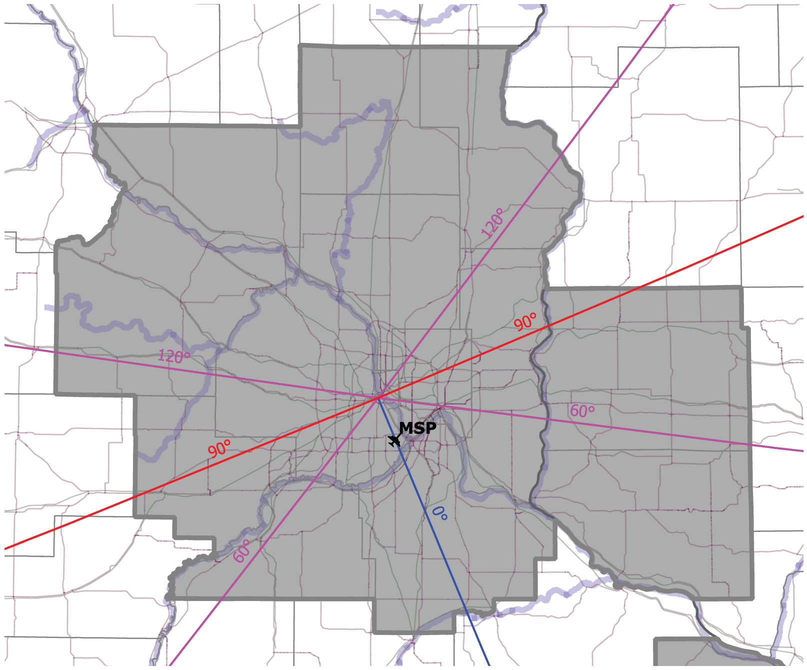

Figure 3: Map of the Minneapolis-St. Paul-Bloomington, MN-WI CBSA showing the axes centered on the CBSA midpoint at angles of 0°, 60°, 90°, and 120° to the direction of the airport. This CBSA is served by the Minneapolis-St. Paul International Airport (MSP).

The results of the estimation are presented in Table 10. The first column presents the baseline results with the employment data aggregated to the entire CBSA. Columns 2 and 3 split the data into locations within 90° of the direction to the airport and those more than 90° from the airport. Columns 4 to 6 divide the data into three zones, divided at 60° and 120° from the direction of the airport. The OLS results are presented in Panel A and the TSLS results are presented in Panel B.

Angle relative to airport	(1) All	(2) 0°-90°	(3) 90°-180°	(4) 0°-60°	(5) 60°-120°	(6) 120°-180°
Panel A. OLS estimation.						
$\ln(airpt_{m,t+1}) - \ln(airpt_{m,t})$	0.010^a	0.012^b	0.022^a	0.009	0.028^b	0.028^b
	(0.003)	(0.005)	(0.007)	(0.006)	(0.012)	(0.014)
$\ln(airpt_{m,t})$	−0.000	0.008^b	0.004	0.006	0.004	0.017^b
	(0.002)	(0.004)	(0.005)	(0.006)	(0.009)	(0.007)
$\ln(emp_{m,t})$	-0.101^a	-0.140^a	-0.168^a	-0.154^a	-0.231^a	-0.222^a
	(0.010)	(0.031)	(0.043)	(0.030)	(0.049)	(0.051)
R^2	0.51	0.33	0.29	0.26	0.21	0.32
Panel B. TSLS estimation. Instrumental variable categories: airline, aircraft class, and distance.						
$\ln(airpt_{m,t+1}) - \ln(airpt_{m,t})$	0.017^b	0.025^b	−0.001	0.024^c	0.071^c	0.037
	(0.009)	(0.011)	(0.029)	(0.015)	(0.039)	(0.058)
$\ln(airpt_{m,t})$	0.002	0.011^b	−0.001	0.010	0.015	0.019
	(0.003)	(0.004)	(0.007)	(0.007)	(0.013)	(0.015)
$\ln(emp_{m,t})$	-0.104^a	-0.142^a	-0.167^a	-0.156^a	-0.233^a	-0.222^a
	(0.010)	(0.031)	(0.041)	(0.030)	(0.049)	(0.050)
First-stage statistic	20.66	20.03	20.25	20.04	20.26	19.88
Overid. p-value	0.65	0.27	0.58	0.24	0.36	0.63
Hausman test p-value	0.17	0.22	0.53	0.17	0.06	0.29
Number of observations	3,078	3,078	3,078	3,078	3,076	3,015

Note: 174 CBSAs for each regression; robust standard errors in parentheses; a, b, c denote significance at 1%, 5%, 10%; number of departing flights used as the measure of airport size; all regressions include CBSA and year fixed effects

Table 10: Effects of airport size on employment within a metropolitan area by direction from the metropolitan-area midpoint relative to the direction to the airport.

The results presented in Table 10 suggest that distance from the airport plays a larger role in the causal effect of airport size on employment than in the correlation between the two variables. That is, changes in airport size make a larger difference to employment in parts of the metropolitan area that are closer to the airport, while changes in airport size are correlated with employment changes in the entire metropolitan area. This is consistent with the level of traffic being driven by demand, which comes from the entire metropolitan area, but accessibility having a larger effect on employment in locations that are nearer the airport.

The results in Table 10 support the validity of the instrument. Were the instrument to be capturing some variation in airport size that is correlated with employment other than through the causal effect of the former on the latter, then a symptom could be that the measured effect applies over the entire metropolitan area. However, distance appears to be more important in the effect of airports on employment estimated using TSLS than in the correlation estimated using OLS, which is reassuring.

4.5 Robustness checks

This section tests the robustness of the main results to a number of alternative sample selections, control variables, and geographical definitions. For brevity, these tests are run for the effects of airports on local employment only, though the results for other outcome variables are similar. The first set of robustness checks tests the implications of various alternative sample selections. The results are presented in Table 11.

	(1) MSA	(2) Pop. $\leq$ 1m	(3) $\geq$10,000 pass.	(4) $\geq$100 flights	(5) Year $\leq$ 2007	(6) No larger near apt.	(7) Dist. inst. excl. CD	(8) 1990 MAs	(9) 50-mile circles
Panel A. OLS estimation.									
$\ln(airpt_{m,t+1}) - \ln(airpt_{m,t})$	0.009^a	0.008^a	0.012^a	0.010^a	0.009^a	0.011^a	0.010^a	0.007^a	0.010^a
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.003)	(0.002)
$\ln(airpt_{m,t})$	0.002	0.001	0.001	0.002	0.003	0.003	0.002	0.002	0.002
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)
$\ln(emp_{m,t})$	-0.087^a	-0.094^a	-0.090^a	-0.092^a	-0.084^a	-0.095^a	-0.091^a	-0.096^a	-0.086^a
	(0.007)	(0.008)	(0.007)	(0.007)	(0.009)	(0.008)	(0.007)	(0.011)	(0.006)
R^2	0.52	0.47	0.51	0.51	0.39	0.52	0.51	0.49	0.56
Panel B. TSLS estimation. Instrumental variable categories: airline, aircraft class, and distance.									
$\ln(airpt_{m,t+1}) - \ln(airpt_{m,t})$	0.020^a	0.017^b	0.018^a	0.019^a	0.022^a	0.016^b	0.020^a	0.017^b	0.020^a
	(0.007)	(0.007)	(0.006)	(0.007)	(0.007)	(0.008)	(0.007)	(0.009)	(0.007)
$\ln(airpt_{m,t})$	0.005^b	0.003	0.003	0.004^c	0.006^b	0.004	0.004^c	0.004^c	0.004^b
	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)	(0.002)	(0.003)	(0.002)
$\ln(emp_{m,t})$	-0.089^a	-0.096^a	-0.091^a	-0.094^a	-0.087^a	-0.096^a	-0.093^a	-0.097^a	-0.088^a
	(0.007)	(0.008)	(0.007)	(0.007)	(0.009)	(0.008)	(0.007)	(0.011)	(0.006)
First-stage statistic	22.79	20.74	31.52	31.16	25.81	55.01	37.22	17.65	25.72
Overid. p-value	0.62	0.74	0.38	0.63	0.88	0.39	0.62	0.67	0.32
Hausman test p-value	0.13	0.23	0.47	0.14	0.04	0.27	0.14	0.22	0.13
Number of observations	3,718	2,926	3,916	4,070	3,128	2,970	4,048	3,388	4,378
Number of metro areas	169	133	178	185	184	135	184	154	199

Note: robust standard errors in parentheses; a, b, c denote significance at 1%, 5%, 10%; all regressions include year and CBSA fixed effects

Table 11: Robustness tests of alternative sample selection criteria.

The first robustness checks in Table 11 test whether the results are sensitive to the size of the metropolitan area. In column 1 the sample is limited to metropolitan statistical areas (MSAs): the CBSAs with at least 100,000 inhabitants in 2009. Column 2 uses a sample limited to CBSA with at most one million inhabitants in 2010. Since the size of the estimates are very similar to the main results in Tables 4 and 6, this suggests that the estimates are unlikely to be driven by particular CBSAs with extreme sizes.

The robustness checks in columns 3 and 4 apply a pair of alternative traffic thresholds for the airports: a minimum of 10,000 departing passengers in each year (the threshold for a *Primary Airport* according to the FAA definitions) and a minimum of 100 departing flights in each year. The coefficient on airport size barely changes, indicating that the results are not sensitive to the choice of airport-size threshold.

The Global Financial Crisis that was at its most intense in 2008 was an unusual period for the US economy. To rule out the results being driven by the unusual events of this period, in column 5 the sample is limited to the period from 1990 to 2007. The coefficient on airport size in this case is if anything slightly larger, suggesting that the results are not an artifact of the Crisis.

As air travel is generally an expensive and time-consuming activity, individuals may travel from airports in neighboring communities. To minimize the possibility of the estimated effects reflecting changes at nearby airports that are outside of the CBSA boundaries, column 6 uses a sample that excludes CBSAs that share a border with a CBSA that had a higher-category airport in 2010 according to the FAA definitions.[14] This restriction decreases the sample size by around one third and increases the strength of the instruments substantially, but the OLS and TSLS coefficients on airport size remain practically unchanged. These estimates suggest that the measured effect on employment is robust to the presence of large airports in nearby areas. This is consistent with the results in Table 10 that show a concentration of the effects of airports even within the CBSA.

With the 'distance' instrument there is a concern about approximate distances being correlated with the region a flight operates from or to – as for example Los Angeles and San Francisco are similar distances from the East Coast cities, and there is a large amount of traffic on these routes. A concern would therefore be that the success of a region's economy would be reflected in flights of similar distances to those operated from a given location. That is, if economic conditions improve in California, then instrumenting for changes in the frequency of flights from Los Angeles by observing changes in flights of a similar distance risks having the variation in the instrument explained by flights from San Francisco and San Diego, which would threaten the exclusion restriction. Column 7 excludes all flights with an endpoint in the same census division in the calculation of the overall growth rates for the 'distance' instrument. This makes no change to the coefficient on the

[14] The FAA airport categories are Large Hub, Medium Hub, Small Hub, Nonhub Primary, Nonprimary Commercial Service, and Reliever.

change in air traffic while in fact the first-stage statistic becomes somewhat larger.

The final two robustness checks addressed in Table 11 concern the geographical aggregation of the data. To be defined as a CBSA in 2009, an area must have a population of at least 10,000 in that year, which is near the end of the period of the data. This could lead to a bias amongst the smaller areas in the sample, as of the areas near the threshold in say 2000, only those with positive growth in recent years are included. To address this concern, column 8 reproduces the estimation with the data aggregated to Metropolitan Area (MA) using the June 1990 definitions. The results are similar to the standard specification.

Two further issues with the CBSA definitions are that they are collections of counties and are ultimately chosen by hand based on individual judgment. Counties are much larger in the Western US, so a CBSA in California that is defined to capture the suburbs of the city necessarily captures more hinterland than a CBSA in the Northeast does. Furthermore, nearby urban cores are more likely to be grouped together in a single CBSA in the West than in the Northeast. To correct for any potential bias that these features may cause, column 9 applies a neutral geographical definition that is defined as locations within a circle of 50-mile radius around each airport that satisfies the 2,500-passenger minimum, but no nearer to any other airport. This definition is explained in detail in Appendix G. Again the results using this definition are similar to those obtained with the data aggregated by CBSA, indicating that the results are not driven by the specific geographical aggregation of the data.

Another potential issue with the estimation is that the instruments could correlate with past rates of growth in airport size or employment. If current growth in employment is related to either of these variables, then the exclusion restriction could be violated. To address this issue, Table 12 presents the OLS and TSLS results from alternative specifications of the system of equations (9) and (10) that include the rates of growth in airport size and employment between times $t-1$ and t. Whenever the past rate of growth is included, the control for the initial size of the respective variable is taken at time $t-1$ rather than t.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Past airport growth			Past emp. growth		Past airport & emp. growth		
	OLS	TSLS	TSLS	OLS	TSLS	OLS	TSLS	TSLS
$\ln(airpt_{m,t+1}) - \ln(airpt_{m,t})$	0.009^{a}	0.013^{c}	0.017^{b}	0.010^{a}	0.017^{b}	0.008^{a}	0.012^{c}	0.016^{b}
	(0.002)	(0.007)	(0.008)	(0.002)	(0.007)	(0.003)	(0.007)	(0.008)
$\ln(airpt_{m,t})$				0.001	0.002			
				(0.002)	(0.002)			
$\ln(emp_{m,t})$	-0.091^{a}	-0.092^{a}	-0.090^{a}					
	(0.007)	(0.007)	(0.008)					
$\ln(airpt_{m,t}) - \ln(airpt_{m,t-1})$	0.010^{a}	0.011^{a}	−0.000			0.010^{a}	0.010^{a}	−0.002
	(0.003)	(0.003)	(0.014)			(0.003)	(0.003)	(0.014)
$\ln(airpt_{m,t-1})$	−0.002	−0.001	−0.002			−0.001	−0.000	−0.002
	(0.002)	(0.002)	(0.003)			(0.002)	(0.002)	(0.003)
$\ln(emp_{m,t}) - \ln(emp_{m,t-1})$				−0.013	−0.018	−0.018	−0.021	−0.016
				(0.028)	(0.029)	(0.028)	(0.028)	(0.029)
$\ln(emp_{m,t-1})$				-0.094^{a}	-0.095^{a}	-0.093^{a}	-0.094^{a}	-0.092^{a}
				(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
R^2	0.52			0.52		0.52		
First-stage statistic		22.43	6.17		24.63		22.10	6.15
Overid. p-value		0.34	0.24		0.77		0.40	0.33
Hausman test p-value		0.46	0.52		0.25		0.43	0.48

Note: 3,864 observations for each regression, representing 184 CBSAs; robust standard errors in parentheses; a, b, c denote significance at 1%, 5%, 10%; number of departing flights used as the measure of airport size; all regressions include year and CBSA fixed effects; all TSLS estimates instrument for airport growth from t to t+1 and columns 3 and 8 instrument for airport growth from t-1 to t, using the 'airline', 'aircraft class', and 'distance' instruments for growth from t to t+1

Table 12: Robustness tests using past rates of growth in airport size and employment.

The OLS results in Table 12 exhibit coefficients on the change in airport size between t and $t+1$ that are similar to the main results. Though the growth in employment is correlated with the growth in airport size in the previous period, the coefficient on the current growth in airport size is only slightly different when the past change in airport size is included.

In the TSLS estimation, the concern is that the instrument could be correlated with past growth in airport size or employment, which in turn influence current employment growth. This could violate the exclusion restriction (12).

Column 2 of Table 12 reproduces the main TSLS estimates with a control for the past rate of growth in airport size. As in the OLS estimation, the past growth in airport size is a significant factor in employment growth between t and $t+1$. If the growth rates for airport size are serially correlated, then controlling for airport growth between $t-1$ and t would reduce the amount of variation in airport growth between t and $t+1$ explained by the instruments. And indeed, the F-statistic on the instruments is smaller than in the main estimates. Serially-correlated airport growth would also imply that some of the effect of current airport growth is captured by the control for past airport growth, which would explain the smaller coefficient on airport growth between t and $t+1$. However, this would apply whether or not the effect of past airport growth is causal.

To determine whether the instruments are correlated with employment growth between t and $t+1$ through past growth in airport size, it is necessary to assess whether any variation in employment growth is explained by past but not current airport growth. To do so, column 3 instruments for the growth in airport size both between $t-1$ and t and between t and $t+1$ using the instruments for airport growth between t and $t+1$. If the coefficient on past airport growth were significant in such a specification, then the exclusion restriction would be violated in the standard specification. However, the coefficient on past airport growth is zero and the coefficient on current airport growth is only slightly different from the main estimate in this specification, alleviating the concern. Note that the first-stage statistic is substantially smaller in this case, as the instruments correlate poorly with past airport growth.

Column 5 of Table 12 uses past employment growth as a control in the TSLS estimation and column 6 instruments for past employment growth using the instruments for airport growth between t and $t+1$. Controlling for past employment growth makes little difference to the estimation and the coefficient on this variable is not significant. The instruments for airport growth between t and $t+1$ explain practically none of the variation in past employment, hence the small first-stage statistic in column 6 and the large magnitude and standard error on the coefficient for past employment growth. Nevertheless, the coefficient on past employment growth is not significant when it is instrumented for, suggesting that correlation between the instruments and past employment growth is not a channel that threatens the exclusion restriction.

Table 13 applies a number of alternative sets of fixed effects in the estimation. To test whether the main results are robust to regional changes that spill beyond the CBSA boundaries, columns 1 through 4 use year-by-census-division and year-by-state fixed effects in place of the year fixed effects in the standard specification. The concern is that the measured effect of airport size on employment could be partly driven by regional-level changes in employment levels that somehow correlate with the instruments. The coefficient on the change in air traffic actually becomes larger with the inclusion of these fixed effects, though they naturally absorb some of the variation in the first stage.

To test whether the results are driven by changes that are concentrated in small or large metropolitan areas, columns 5 and 6 of Table 13 use year-by-MSA-status fixed effects in place of the year fixed effects, where MSA status is defined according to the 2009 CBSA definitions. The results are similar to those in the standard specification.

	(1)	(2)	(3)	(4)	(5)	(6)
	Year-by-census-div. fixed effects		Year-by-state fixed effects		Year-by-MSA-status fixed effects	
	OLS	TSLS	OLS	TSLS	OLS	TSLS
$\ln(airpt_{m,t+1}) - \ln(airpt_{m,t})$	0.011^{a}	0.022^{a}	0.012^{a}	0.030^{a}	0.010^{a}	0.019^{a}
	(0.002)	(0.007)	(0.003)	(0.009)	(0.002)	(0.007)
$\ln(airpt_{m,t})$	0.003^{b}	0.006^{a}	0.004^{b}	0.008^{a}	0.001	0.003
	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)
$\ln(emp_{m,t})$	-0.099^{a}	-0.101^{a}	-0.103^{a}	-0.106^{a}	-0.090^{a}	-0.092^{a}
	(0.008)	(0.008)	(0.008)	(0.008)	(0.007)	(0.007)
R^2	0.56		0.66		0.51	
First-stage statistic		25.90		20.46		25.38
Overid. p-value		0.05		0.01		0.63
Hausman test p-value		0.09		0.01		0.11

Note: 4,048 observations for each regression, representing 184 CBSAs; robust standard errors in parentheses; a, b, c denote significance at 1%, 5%, 10%; all regressions include CBSA fixed effects as well as the fixed effects stated in the table headers

Table 13: Robustness tests using fixed effects that interact year by census division, state, and MSA status.

5 Conclusion

This paper estimates the effects of changes in airport size on employment and other economic outcomes in the metropolitan area served by the airport. This topic is important for the evaluation of policy, as airports are expensive to construct or expand and normally improved using public funds. Nevertheless, the existing evidence of the economic effects of airports is limited, due largely to the difficulties inherent in measuring the effects. There are many reasons why airport size and local economic outcomes may be correlated. To generate reliable estimates of the causal effects of airports, it is necessary to address the problem of the endogenous determination of airport size. To do so I develop an original technique that measures the effects of airports using variation in overall characteristics of the air travel network.

The main findings are that airport size has a positive effect on local employment, with an elasticity of 0.02, and on local GDP, with an elasticity of 0.035. This corresponds to approximately three jobs created outside of the airport for each job created at the airport by an exogenous increase in air traffic. As the effect on GDP is larger than that on employment, output per worker also appears to be positively affected by airport size. Furthermore, the effect on employment appears to be concentrated in the parts of the metropolitan area that are nearest the airport.

The effect on employment that I estimate is smaller than what previous studies have found. For instance, Green (2007) found an elasticity of 0.03 for the effect of passengers per capita on employment growth, and Blonigen and Cristea (2012) found an elasticity of between 0.07 and 0.12 for the effect of the number of passengers on employment. A possible explanation for the relatively small size of the coefficient I estimate is that the technique is more effective in addressing the problems of airport sizes and economic outcomes being simultaneously determined. In addition, as the estimates in this paper reflect the effects of airport size on employment over short time intervals, it is possible that the full, long-term effect of a change in airport size takes more time to accumulate.

To further understand the effects of airports on the local economy, I estimate the effects of airports on the number of firms, on wages, and on the employment rate. Airport size is found to have a positive effect on the number of firms and on wages. The effect of airport size on the employment rate is positive but smaller in magnitude than the effect on the number of employees. The relative magnitudes suggest that approximately half of the effect of airports on local employment is due to a net increase in the employment of local residents and half is due to workers migrating to the metropolitan area to take up new jobs.

The allocation of newly-created jobs between existing residents and migrants highlights an important point about scope. This paper estimates the effects of airports in terms of a given metropolitan area in isolation: controlling for national trends, how does employment within the metropolitan area respond to a change in airport size? This question is relevant to policy makers at the city or state level. The problem faced by the federal government, of where to locate airports and of what sizes, is more complex. Some pairs of airports will be complements, as an airport is only useful if there are potential destinations, while others will be in competition. The contribution of an airport to the network is therefore a more complicated matter than its contribution to the local area. In addition, an increase in employment or output in a given area that is simply a reallocation of activity between locations is not necessarily beneficial at the national level. This paper provides a provisional answer to this last point – that roughly half of the additional jobs are simply a reallocation between metropolitan areas – but the question of how to design the optimal national or international air network is a matter for future research.

The estimates of the effects on employment by broad industrial sector indicate that airport size has a positive effect on service employment but no measurable effect on manufacturing employment. These results are consistent with those based on cross-sectional variation in a previous paper by the same author (Sheard, 2014), in which airport size was found to have a positive effect on the share of some types of services but no effect on the share of manufacturing. However, in the previous paper it was not clear whether the overall level of employment was due to an overall increase in employment or simply a reallocation between sectors. The results presented here suggest more clearly that services expand without displacing manufacturing activity. I also find that airport size has a positive effect on employment in construction, but no measurable effect on wholesale and retail trade or on transportation and utilities.

The technique proposed in this paper to measure the effects of airports would be straightforward to apply in future studies of the effects of airport. The technique could also be applied to other types of transportation infrastructure such as roads, railways, and ports. Additional applications could include non-transportation infrastructure such as electrical supply and communications networks.

The locations of roads and railways depend substantially on geographical factors and historical infrastructure, allowing such variables to be used as instruments as has been done in previous work. The classifications of airlines and aircraft may also not have clear analogues in, say, automobile travel. Nevertheless, the technique I propose could be useful in analyzing roads and railways as it does not require data on geography or historical infrastructure that are often difficult to obtain and quantify. On the other hand, the technique would be readily applicable to studying the effects of ports.

The technique has two main advantages over alternative identification strategies. The first is that, as opposed to instruments that explain cross-sectional variation in current infrastructure, it does not require geographical or historical data that are often difficult to obtain or quantify. The second is that calculating the instruments simply requires data on recent levels of the infrastructure and an appropriate category by which to divide them up. This paper uses three distinct categories for airport size. It could be easier to find appropriate categories for other types of infrastructure than it would be to find alternative ways of identifying the effects such as instruments for cross-sectional variation or the timing of policy changes.

Another potential advantage of the technique is that it facilitates estimating the short-term effect of changes in infrastructure. That is, it facilitates estimating the effects of an investment on local employment in the next few years, whereas techniques that rely on cross-sectional variation may only be able to explain long-term effects. Short-term effects are more relevant to some types of policy evaluation than the assessment of effects that could take several decades to materialize. In the long run, technology may have changed such that a new runway is no longer beneficial, as for example the types of aircraft then in use no longer require its carrying capacity or because advances in train technology or increased fuel prices have led to long-distance travel being conducted primarily by rail.

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A Categories used to construct the instruments

The ‘airline’ instrument is constructed using the airline classification presented in Table 14, which lists the airlines in descending order of the number of flights operated. The airlines are grouped according to the *Unique Carrier Code* assigned by the BTS, which tracks changes in airline codes over time and separates different airlines that used the same code in different periods. Airlines that did not have an average of at least 10 daily flights and 100 daily passengers in at least one year between 1990 and 2013 are excluded, though naturally this only makes a slight difference to the instrument.

The numbers of flights and passengers listed in Table 14 are the aggregate amounts of traffic operated by the airline between 1990 and 2013 with an origin or destination within the contiguous United States.

Airline code	Airline name	Number of flights	Number of pass. ('000)	Airline code	Airline name	Number of flights	Number of pass. ('000)
WN	Southwest Airlines	20,971,217	1,938,582	TA	Taca International Airlines	217,180	22,326
DL	Delta Air Lines	19,847,254	2,233,332	JM	Air Jamaica	215,426	24,888
AA	American Airlines	19,284,845	2,089,688	J7	Valujet Airlines	212,960	14,023
UA	United Air Lines	15,423,995	1,718,322	YR	Grand Canyon Airlines	212,045	2,677
US	US Airways	15,157,817	1,293,067	VS	Virgin Atlantic Airways	210,750	61,482
NW	Northwest Airlines	10,323,029	992,479	KE	Korean Air Lines	206,721	47,178
CO	Continental Air Lines	9,319,004	928,087	ML (1)	Midway Airlines (Chicago, IL)	199,366	11,262
MQ	American Eagle Airlines	8,773,047	270,314	C8 (1)	Chicago Express Airlines	185,095	3,879
EV	Atlantic Southeast Airlines	6,361,139	221,125	HRZ	Allegheny Airlines	183,669	3,422
OO	SkyWest Airlines	6,325,426	229,169	CP (1)	Canadian Airlines	183,563	16,085
XE	ExpressJet Airlines	6,052,951	189,996	WS	Westjet	169,985	20,135
QX	Horizon Air	4,068,794	127,343	WST	West Isle Air	159,682	146
AS	Alaska Airlines	3,704,828	344,339	KL	KLM Royal Dutch Airlines	153,061	37,949
HP	America West Airlines	3,629,649	338,372	NJ	Vanguard Airlines	147,636	11,046
YV	Mesa Airlines	3,359,469	120,907	ZX	Air Georgian	138,291	1,193
TW	Trans World Airways	3,267,656	280,155	U2	UFS	136,516	4,207
FL	AirTran Airways Corporation	2,990,459	264,667	BF	MarkAir	131,119	6,843
OH	Comair	2,964,008	105,357	UP	Bahamasair	130,206	7,771
XJ	Mesaba Airlines	2,947,125	78,732	GQ	Big Sky Airlines	126,874	1,070
9E	Pinnacle Airlines	2,854,168	109,599	AV	Avianca	125,017	14,567
ZW	Air Wisconsin	2,771,708	102,864	IB	Iberia	121,203	21,503
AX	Trans States Airlines	2,451,303	53,395	CM	Compania Panamena	110,695	10,504
B6	JetBlue Airways	2,144,887	240,236	BW	Caribbean Airlines	104,215	11,322
RP	Chautauqua Airlines	2,032,540	68,447	KW	Carnival Air Lines	99,168	10,535
AC	Air Canada	1,527,766	114,606	U5	USA 3000 Airlines	95,257	11,900
HA	Hawaiian Airlines	1,467,961	149,456	3C	Regions Air	90,874	676
17	Piedmont Airlines	1,465,350	35,033	KP	Kiwi International	75,213	6,382
9K	Cape Air	1,379,522	7,435	SR	Swissair Transport	72,395	13,909
OW	Executive Airlines	1,347,280	43,551	RD	Ryan International Airlines	71,244	8,408
16	PSA Airlines	1,249,632	47,535	PD	Porter Airlines	70,857	2,662
F9	Frontier Airlines	1,182,452	118,245	RG	Varig	69,911	11,755
KH	Aloha Air Cargo	1,097,855	87,339	KN	Morris Air Corporation	66,201	6,828
YX	Republic Airlines	1,074,939	64,387	GL	Miami Air International	66,119	4,963
9L	Colgan Air	956,816	19,419	N7	National Airlines	63,190	7,126
S5	Shuttle America	892,738	41,317	L3	Lynx Aviation / Frontier Airlines	62,578	2,873
ZK	Great Lakes Airlines	832,976	6,320	MG	Champion Air	61,240	7,406
NK	Spirit Air Lines	780,340	93,831	1DQ	Island Airlines	58,609	380
DH	Independence Air	769,234	22,789	W7	Western Pacific Airlines	58,319	4,503
YX (1)	Midwest Airlines	734,483	40,757	5D	Aerolitoral	55,484	2,022
OE	WestAir Airlines	694,033	8,518	JJ	Transportes Aeros Meridiona	51,060	8,935
TZ	ATA Airlines	659,165	88,184	WV (1)	Air South	50,628	3,087
3M	Silver Airways / Gulfstream Int'l	647,425	7,363	0JQ	Vision Airlines	45,706	1,952
BA	British Airways	621,727	130,109	LGQ	Lineas Aereas Allegro	45,114	5,187
HQ (1)	Business Express	620,932	7,627	SLQ	Sky King	43,745	3,277
QK	Air Canada Regional	619,207	19,062	PCQ	Pace Airlines	40,579	2,849
MX	Mexicana	577,923	54,741	Y4	Volaris	39,493	4,483
C5	CommutAir	476,663	8,175	NA	North American Airlines	38,530	4,511
AM	Aeromexico	456,934	39,329	T9	TransMeridian Airlines	38,441	4,772
KS	Peninsula Airways	436,971	3,009	8N	Flagship Airlines	38,139	983
ZV	Air Midwest	417,503	2,907	FF	Tower Air	31,186	11,019
G7	GoJet Airlines / United Express	375,521	19,444	0MQ	Multi-Aero / Air Choice One	30,977	116
LH	Lufthansa German Airlines	375,040	86,450	E9	Boston-Maine Airways	27,409	363
QQ	Reno Air	351,058	30,156	W9	Eastwind Airlines	25,763	1,142
CP	Compass Airlines	346,645	20,276	P9	Pro Air	22,643	1,182
G4	Allegiant Air	333,919	44,104	PN	Pan American Airways (1998–2004)	20,365	1,270
AL	Skyway Airlines	297,374	4,405	EM	Empire Airlines	18,590	269
JI (1)	Midway Airlines (Morrisville, NC)	295,780	14,887	APN	Aspen Airways	14,490	552
EA	Eastern Air Lines	290,628	23,372	JX	Southeast Airlines	12,677	1,313
AF	Air France	285,265	62,953	1AQ	Charter Air Transport	9,417	187
F8	Freedom Airlines	277,230	10,261	SX	Skybus Airlines	9,314	932
VX	Virgin America	258,571	28,229	RS	Sky Regional Airlines	8,414	443
KAH	Kenmore Air Harbor	251,888	1,124	BE	Braniff International Airlines	6,832	667
JL	Japan Air Lines	251,002	65,032	PA (2)	Pan American Airways (1996–1998)	6,071	847
PA (1)	Pan American World Airways	231,051	25,781	T3	Tristar Airlines	6,033	281
K5	SeaPort Airlines	226,585	736	A7 (1)	Air 21	5,935	217
TB (1)	USAir Shuttle	225,587	15,666	ZA	Access Air	4,261	202
SY	Sun Country Airlines / MN Airlines	221,632	26,674				

Note: the air traffic figures represent all flights originating or terminating in the contiguous US between 1990 and 2013; the numbers in parentheses in the airline codes are defined by the BTS to differentiate airlines that used the same code at different times

Table 14: Airline classification used to calculate the 'airline' instrument.

The 'aircraft model' instrument is constructed using the classification of aircraft models presented in Table 15. The minimum standard for inclusion in the classification is that a model must have been used for at least one daily flight and one daily passenger in at least one year between 1990 and 2013. The air traffic variables are the aggregates of all flights with an origin or destination in the contiguous US.

Index	Aircraft model	Number of flights	Number of pass. ('000)	Index	Aircraft model	Number of flights	Number of pass. ('000)
1	Aérospatiale/Aeritalia ATR 42/72	3,745,807	120,106	49	Boeing 787-800	7,295	1,239
2	Aérospatiale-BAC Concorde	26,160	1,365	50	Bombardier CRJ100/200	15,801,704	563,528
3	Airbus A300-100/200	211,688	32,819	51	Bombardier CRJ700/705/900	5,938,797	324,259
4	Airbus A300-600	609,409	111,639	52	British Aerospace BAe-146	1,335,154	61,485
5	Airbus A310-200	42,460	5,741	53	British Aerospace BAe-ATP	208,109	6,375
6	Airbus A310-300	154,234	21,117	54	British Aerospace Jetstream	1,881,310	21,047
7	Airbus A318	164,497	13,987	55	Cessna 172/180/182/185	75,689	75
8	Airbus A319	5,895,271	550,435	56	Cessna 205/206/207/209/210	1,783,621	2,846
9	Airbus A320-100/200	8,700,927	978,130	57	Cessna 208	1,437,219	5,494
10	Airbus A321	782,612	113,310	58	Cessna 402	1,421,242	6,747
11	Airbus A330-200	584,148	124,744	59	Cessna Citation II	2,409	17
12	Airbus A330-300	62,582	15,677	60	Cessna Citation X	4,270	14
13	Airbus A340	30,116	5,669	61	Convair CV-580	12,851	350
14	Airbus A340-200	346,283	71,375	62	De Havilland DHC2	398,274	947
15	Airbus A340-300	72,256	14,737	63	De Havilland DHC3	157,678	951
16	Airbus A340-500	34,288	5,808	64	De Havilland DHC6	466,970	5,161
17	Airbus A340-600	77,395	19,321	65	De Havilland DHC7	71,681	1,914
18	Airbus A380-800	26,043	10,295	66	De Havilland DHC8	6,057,841	176,604
19	Beechcraft Baron	11,816	17	67	Dornier 228	19,807	271
20	Beechcraft King Air	35,208	142	68	Dornier 328	810,925	16,054
21	Beechcraft Super King Air	4,118,701	33,933	69	Embraer 110	109,431	710
22	Boeing 707-100	4,594	374	70	Embraer 120	4,014,302	67,169
23	Boeing 707-300	6,101	684	71	Embraer 135/140/145	14,091,754	481,033
24	Boeing 717-200	2,863,023	245,857	72	Embraer 170/175	2,326,290	126,634
25	Boeing 727-100	446,738	29,196	73	Embraer 190	1,008,403	76,307
26	Boeing 727-200/231	9,938,116	902,345	74	Fairchild F-27	106,539	2,394
27	Boeing 737-100/200	9,910,672	685,813	75	Fairchild Swearingen Metroliner	809,851	7,455
28	Boeing 737-300	20,425,798	1,778,562	76	Fokker 70/100	2,524,254	150,433
29	Boeing 737-400	3,453,398	322,898	77	Fokker F28	855,111	34,629
30	Boeing 737-500	4,510,634	353,284	78	Grumman G-73 Mallard	12,775	141
31	Boeing 737-600	9,310	769	79	Gulfstream G150/G200/G450	3,188	9
32	Boeing 737-700	8,941,419	890,475	80	Gulfstream II/III/IV/V	4,335	17
33	Boeing 737-800	5,623,594	666,324	81	Ilyushin 62	10,693	891
34	Boeing 737-900	584,817	82,563	82	Ilyushin 96	3,127	340
35	Boeing 747-100	346,771	99,503	83	Lockheed L-1011	773,329	152,285
36	Boeing 747-200/300	711,225	189,726	84	McDonnell Douglas DC-8	54,331	6,440
37	Boeing 747-400	1,588,373	440,904	85	McDonnell Douglas DC-9	31,307,843	2,600,436
38	Boeing 747-400F	6,470	30	86	McDonnell Douglas DC-10	1,514,243	292,500
39	Boeing 747-8	2,034	659	87	McDonnell Douglas MD-11	295,534	55,894
40	Boeing 747C	52,595	10,810	88	McDonnell Douglas MD-90	578,610	64,572
41	Boeing 747SP	42,698	7,315	89	Nihon YS-11	5,320	74
42	Boeing 757-200	12,260,944	1,650,587	90	Pilatus Britten-Norman BN2/A	169,277	716
43	Boeing 757-300	440,405	82,663	91	Pilatus PC-12	96,638	377
44	Boeing 767-200	1,465,849	196,321	92	Piper PA-18/23/28/31/32/34/39	1,221,694	2,951
45	Boeing 767-300	3,369,742	573,714	93	Piper PA-30/31T	24,613	63
46	Boeing 767-400	350,921	73,549	94	Quest Kodiak 100	1,724	11
47	Boeing 777-200/233	1,500,021	313,674	95	Saab 340	5,276,899	96,223
48	Boeing 777-300/333	94,050	23,632	96	Shorts 330/360	307,755	5,072

Note: the air traffic figures represent all flights originating or terminating in the contiguous US between 1990 and 2013

Table 15: Aircraft classification used to calculate the ‘aircraft model’ instrument.

The aircraft classes used to construct the ‘aircraft class’ instrument are listed in Table 16. These are based on the *Aircraft Type Group* variable specified in the BTS data. Sufficiently broad or narrow categories do not yield relevant instruments. Therefore, the groups for the jet aircraft are broken down by the numbers of seats in the aircraft, to give a finer indication of aircraft size.

Index	Aircraft class	Number of flights	Number of pass. ('000)
0	Piston, 1-Engine/Combined Piston/Turbine	3,011,365	5,922
1	Piston, 2-Engine	2,299,759	9,699
2	Piston, 3-Engine/4-Engine	2,759	0
3	Helicopter/STOL	23,079	45
4	Turbo-Prop, 1-Engine/2-Engine	29,389,928	559,415
5	Turbo-Prop, 4-Engine	89,723	2,294
6.1	Jet, 2-Engine, 1-99 seats	44,689,416	1,850,684
6.2	Jet, 2-Engine, 100-149 seats	85,678,456	7,355,290
6.3	Jet, 2-Engine, 150-199 seats	29,997,353	3,751,807
6.4	Jet, 2-Engine, 200+ seats	7,450,016	1,384,670
7.1	Jet, 3-Engine, 1-99 seats	18,421	471
7.2	Jet, 3-Engine, 100-149 seats	10,370,122	931,137
7.3	Jet, 3-Engine, 150-199 seats	2,363	73
7.4	Jet, 3-Engine, 200+ seats	2,580,807	500,615
8.1	Jet, 4-Engine/6-Engine, 1-99 seats	1,341,858	61,517
8.2	Jet, 4-Engine/6-Engine, 100-199 seats	57,378	4,132
8.3	Jet, 4-Engine/6-Engine, 200-299 seats	550,173	106,643
8.4	Jet, 4-Engine/6-Engine, 300-399 seats	2,434,252	661,685
8.5	Jet, 4-Engine/6-Engine, 400+ seats	372,814	109,797

Note: the air traffic figures represent all flights originating or terminating in the contiguous US between 1990 and 2013

Table 16: Aircraft classification used to calculate the ‘aircraft class’ instrument.

The ‘number of seats’ instrument is constructed using the set of ranges presented in Table 17.

Index	Number of seats		Number of flights	Number of pass. ('000)
	Minimum	Maximum		
1	1	4	153,945	142
2	5	9	6,776,805	21,032
3	10	24	6,994,647	60,877
4	25	49	47,580,195	1,396,211
5	50	99	19,360,716	1,011,786
6	100	149	96,079,419	8,288,134
7	150	199	30,026,253	3,754,303
8	200	299	10,456,589	1,962,593
9	300	399	2,528,303	685,317
10	400	499	403,170	115,498

Note: the air traffic figures represent all flights originating or terminating in the contiguous US between 1990 and 2013

Table 17: Number ranges used to calculate the ‘number of seats’ instrument.

The ‘distance’ instrument is constructed using the set of ranges of distance flown in miles presented in Table 18. A handful of flight segments in the data are longer than 10,000 miles; these are simply excluded.

Index	Distance (miles)		Number of flights	Number of pass. ('000)
	Minimum	Maximum		
1	0	250	55,467,567	2,200,513
2	250	500	56,767,157	3,602,312
3	500	750	34,199,667	2,658,451
4	750	1,000	23,506,638	2,141,590
5	1,000	1,250	15,701,574	1,626,908
6	1,250	1,500	7,281,741	809,183
7	1,500	1,750	7,756,627	971,052
8	1,750	2,000	3,598,143	462,932
9	2,000	2,500	5,519,046	739,832
10	2,500	3,000	2,023,996	313,789
11	3,000	3,500	1,023,637	192,125
12	3,500	4,000	2,013,847	401,182
13	4,000	4,500	1,806,370	370,075
14	4,500	5,000	969,423	185,752
15	5,000	6,000	1,436,347	338,110
16	6,000	7,000	802,921	197,819
17	7,000	8,000	270,473	69,453
18	8,000	9,000	61,571	12,873
19	9,000	10,000	6,859	656

Note: the air traffic figures represent all flights originating or terminating in the contiguous US between 1990 and 2013

Table 18: Distance ranges used to calculate the 'distance' instrument.

B Smoothing for continuous category variables

For the overall growth rates by the number of seats and the distance, the mean growth rates are smoothed across the category ranges. The technique used to smooth the rates is to take a weighted average of the raw growth rates across neighboring ranges. The weights are a discrete approximation of a normal distribution, adjusted for the number of observations for each range. Where the observed value for the growth rate in number of seats or distance category c is g_c, the number of observations is n_c, and the smoothed value $\tilde{g}_c$ is calculated as follows:

$$\tilde{g}_c = \frac{n_{c-2}g_{c-2} + 4n_{c-1}g_{c-1} + 6n_c g_c + 4n_{c+1}g_{c+1} + n_{c+2}g_{c+2}}{n_{c-2} + 4n_{c-1} + 6n_c + 4n_{c+1} + n_{c+2}} \tag{13}$$

An example of the smoothing calculation is presented in Figure 4, for a set of observed growth rates by distance range. The smoothed line obviously has less variation than the raw data. The importance of the numbers of observations can also be seen from the diagram, as the distance ranges that have fewer observations have smoothed values that conform relatively closely to the neighboring ranges' raw values.

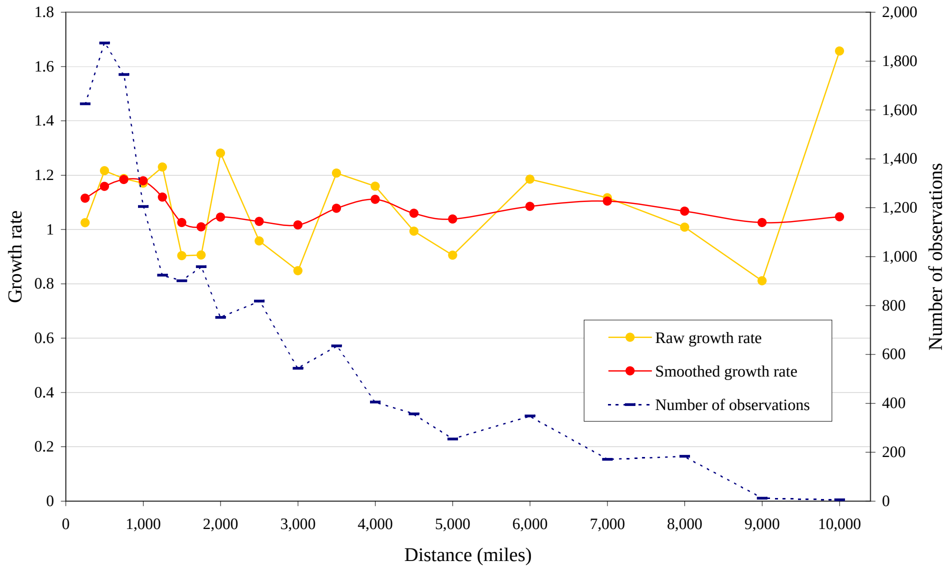

Figure 4: Example of distance-smoothing calculation.

C Instrument category growth rates and CBSA characteristics

A potential concern with the instruments is that certain airlines, types of aircraft, or flights of a certain distance may operate in certain types of metropolitan areas. If airlines or aircraft with increasing overall traffic levels tend to operate in metropolitan areas with higher anticipated growth rates, then the exclusion restriction would be violated. This appendix tests whether there is any systematic relationship between the sizes of the metropolitan areas that airlines, aircraft, or flights of a given distance operate from and the overall growth rates of the respective categories.

The first step of this analysis is to find the mean number of departing flights and mean total employment of the CBSAs that each airline, aircraft class, or flight in a given distance range operates out of. These are calculated using the following expression, in which c, m, and t denote the category item, metropolitan area, and year, respectively, $A_{c,m,t}$ is the number of departing flights, and $S_{m,t}$ is the size of the metropolitan area in terms of either air traffic or total employment:

$$\bar{S}_{c,t} = \frac{\sum_{m} A_{c,m,t} \cdot S_{c,m,t}}{\sum_{m} A_{c,m,t}} \tag{14}$$

Figure 5 plots the overall growth rates of the airlines, aircraft classes, and distance ranges against the mean CBSA numbers of departing flights and employment from (14).

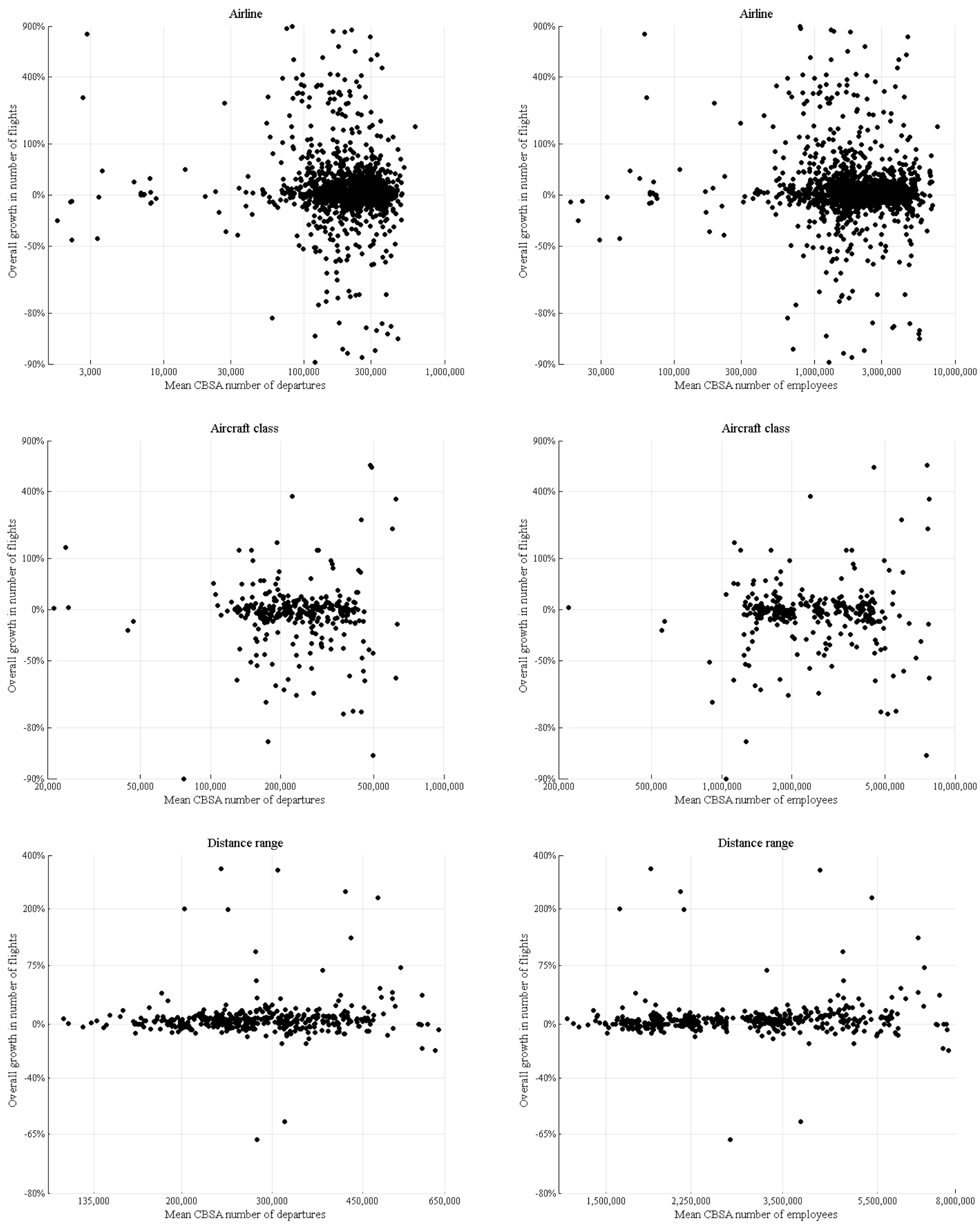

Figure 5: Plots of mean level of air traffic and total employment of the CBSAs for each airline, aircraft class, and distance range against the overall growth rates of the respective categories.

No systematic relationship between the mean CBSA size variables and the overall growth rates of the categories is evident from Figure 5. To test whether there is such a relationship, the following equation is estimated for each mean CBSA size variable and each category using weighted least squares (WLS), where $a = \ln(A)$ and $\bar{s} = \ln(\bar{S})$:

$$a_{c,t+1} - a_{c,t} = \bar{s}_{c,t} + \varepsilon_{c,t} \tag{15}$$

The results from the estimation of (15) are displayed in Table 19. None of the coefficients on the mean CBSA number of departures or the mean CBSA employment is significantly zero. Furthermore, the R^2 values indicate that these variables explain practically none of the variation in the overall growth in air traffic by category. These results suggest no correlation between the CBSAs operated in by airlines, aircraft classes, or flights over specific distance ranges and the growth rates of those category items.

	(1) WLS	(2) WLS	(3) WLS	(4) WLS	(5) WLS	(6) WLS
Instrumental-variable category	Airline	Airline	Aircract class	Aircract class	Distance	Distance
$\ln(dep_{c,t+1}) - \ln(dep_{c,t})$	−0.010		−0.043		−0.019	
	(0.017)		(0.029)		(0.018)	
$\ln(emp_{c,t+1}) - \ln(emp_{c,t})$		−0.025		−0.020		0.006
		(0.016)		(0.029)		(0.014)
R^2	0.00	0.00	0.00	0.00	0.00	0.00
Number of observations	1,572	1,572	327	327	427	427

Note: dependent variable for each regression: change in log overall number of departures; robust standard errors in parentheses; a, b, c denote significance at 1%, 5%, 10%

Table 19: Results for the estimation of the overall growth in traffic for each airline, aircraft class, and distance range by the mean CBSA number of departing flights and employment.

D TSLS results without fixed effects and controls for initial air traffic and employment

The results for the TSLS estimation of (9) and (10) with different selections of fixed effects and controls are presented in Table 20. Column 1 displays the results generated using no fixed effects and no controls for the initial number of flights or employment. Columns 2 through 4 add year and CBSA fixed effects. Columns 5 through 7 add the controls for initial levels of air traffic and employment.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A. First-stage estimation.							
'Airline' instrument	0.214^a	0.218^a	0.212^a	0.216^a	0.209^a	0.216^a	0.209^a
	(0.046)	(0.046)	(0.046)	(0.046)	(0.041)	(0.046)	(0.042)
'Aircraft class' instrument	0.198^a	0.215^a	0.162^a	0.188^a	0.328^a	0.189^a	0.335^a
	(0.058)	(0.065)	(0.058)	(0.067)	(0.064)	(0.067)	(0.063)
'Distance' instrument	0.740^a	0.767^a	0.640^a	0.637^b	0.378	0.638^b	0.376
	(0.098)	(0.106)	(0.150)	(0.259)	(0.252)	(0.259)	(0.251)
$\ln(airpt_{m,t})$					-0.208^a		-0.214^a
					(0.020)		(0.020)
$\ln(emp_{m,t})$						0.039	0.179^a
						(0.050)	(0.046)
R^2	0.24	0.26	0.26	0.27	0.37	0.27	0.37
Panel B. Second-stage estimation. Instrumental variable categories: airline, aircraft class, and distance.							
$\ln(airpt_{m,t}) - \ln(airpt_{m,t-1})$	0.041^a	0.052^a	0.011^b	0.021^a	0.022^a	0.019^a	0.020^a
	(0.006)	(0.007)	(0.005)	(0.007)	(0.007)	(0.007)	(0.007)
$\ln(airpt_{m,t})$					0.001		0.004^c
					(0.002)		(0.002)
$\ln(emp_{m,t})$						-0.090^a	-0.093^a
						(0.006)	(0.007)
First-stage statistic	106.90	93.22	30.96	19.46	28.93	19.41	29.67
Overid. p-value	0.01	0.01	0.41	0.32	0.34	0.47	0.63
Hausman test p-value	0.00	0.00	0.89	0.06	0.02	0.13	0.13
CBSA fixed effects		Y		Y	Y	Y	Y
Year fixed effects			Y	Y	Y	Y	Y

Note: 4,048 observations for each regression, representing 184 CBSAs; robust standard errors in parentheses; a, b, c denote significance at 1%, 5%, 10%; number of departing flights used as the measure of airport size; number of employees used as the local economy measure

Table 20: TSLS results with and without the year and CBSA fixed effects and the controls for the initial levels of airport size and employment.

The results in Table 20 suggest that the inclusion of year and CBSA fixed effects are important for the estimation, but that the initial number of flights and employment controls make little difference. Without the fixed effects the instruments are far stronger, suggesting that there are idiosyncratic differences between years and CBSAs. The coefficient on the change in airport size in the second stage varies with the inclusion of the fixed effects, implying employment growth that is idiosyncratic to the years and metropolitan areas that is captured in the fixed effects. The controls for initial air traffic and employment make little difference to the estimates in either the first or the second stage.

E GMM estimation

Table 21 presents a reproduction of the main TSLS results in Table 6 using a generalized method of moments (GMM) estimator.

Airport-size measure	(1) TSLS Flights	(2) TSLS Flights	(3) TSLS Flights	(4) TSLS Flights	(5) TSLS Seats	(6) TSLS Pass.	(7) TSLS Air access
Panel A. Dependent variable: Change in log CBSA-level employment.							
$\ln(airpt_{m,t+1}) - \ln(airpt_{m,t})$	0.016^b	0.029^b	0.024^b	0.020^a	0.020^b	0.028^b	0.012^b
	(0.008)	(0.011)	(0.012)	(0.007)	(0.010)	(0.012)	(0.005)
$\ln(airpt_{m,t})$	0.003	0.005^c	0.004	0.004^c	0.003	0.005^c	0.002
	(0.002)	(0.003)	(0.003)	(0.002)	(0.003)	(0.002)	(0.002)
$\ln(emp_{m,t})$	-0.092^a	-0.094^a	-0.093^a	-0.093^a	-0.092^a	-0.092^a	-0.092^a
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
First-stage statistic	26.66	47.71	16.21	29.67	21.25	20.62	23.99
Overid. p-value				0.63	0.21	0.52	0.12
Hausman test p-value	0.47	0.09	0.22	0.13	0.31	0.19	0.23
Panel B. Dependent variable: Change in log CBSA-level GDP.							
$\ln(airpt_{m,t+1}) - \ln(airpt_{m,t})$	0.034^b	0.030^c	0.032^c	0.032^a	0.030^c	0.041^b	0.019^a
	(0.015)	(0.015)	(0.016)	(0.011)	(0.016)	(0.019)	(0.007)
$\ln(airpt_{m,t})$	0.005	0.005	0.005	0.005	0.002	0.005	0.004^c
	(0.004)	(0.004)	(0.004)	(0.003)	(0.004)	(0.004)	(0.002)
$\ln(gdp_{m,t})$	-0.082^a	-0.081^a	-0.081^a	-0.082^a	-0.080^a	-0.079^a	-0.081^a
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
First-stage statistic	26.41	47.07	16.00	29.27	20.78	20.34	23.43
Overid. p-value				0.99	0.71	0.92	0.64
Hausman test p-value	0.22	0.34	0.30	0.10	0.30	0.24	0.22
‘Airline’ instrument	Y			Y	Y	Y	Y
‘Aircraft class’ instrument		Y		Y	Y	Y	Y
‘Distance’ instrument			Y	Y	Y	Y	Y

Note: 4,048 observations for each regression, representing 184 CBSAs; robust standard errors in parentheses; a, b, c denote significance at 1%, 5%, 10%; all regressions include CBSA and year fixed effects

Table 21: Second-stage estimation of the effects of airport size on employment and GDP using GMM.

F Industry classification from SIC and NAICS codes

Table 22 presents the classification of the employment data from the County Business Patterns into industries according to the SIC and NAICS codes.

Industry	SIC codes	NAICS codes
Construction	15-17 (“Construction”)	23 (“Construction”)
Manufacturing	20-39 (“Manufacturing”) 50-51 (“Wholesale Trade”)	31-33 (“Manufacturing”) 42 (“Wholesale Trade”)
Retail trade	52-59 (“Retail Trade”)	44-45 (“Retail Trade”)
Transportation	40-49 (“Transportation & Public Utilities”)	22 (“Utilities”) 48-49 (“Transportation and Warehousing”)
Services	60-67 (“Finance, Insurance, Real Estate”) 70-89 (“Services”)	51 (“Information”) 52 (“Finance and Insurance”) 53 (“Real Estate and Rental and Leasing”) 54 (“Professional, Scientific, and Technical Services”) 55 (“Management of Companies and Enterprises”) 56 (“Administrative and Support Services”) 81 (“Other Services (except Public Administration)”)

Table 22: Industry definitions from the two-digit SIC and NAICS classifications.

G Metropolitan-area definition based on distance from airport

As a robustness check I aggregate the data according to geographical areas that are neutral to county definitions and individual instances of human judgment. The areas are defined as the space within a 50-mile radius of an airport that satisfies the minimum passenger condition, but no nearer any other such airport. The areas are thus based on circles, but where two airports are within 100 miles of each other the respective circles have segments removed along a straight line defined by equal distances to the two airports. The minimum passenger condition is that the airport must host at least 2,500 departing passengers in each year from 1990 to 2013. Figure 6 is a map of these areas, overlaid on the CBSAs in the main sample to illustrate how the two definitions compare. Note that some airports that satisfy the minimum passenger condition are not within CBSAs.

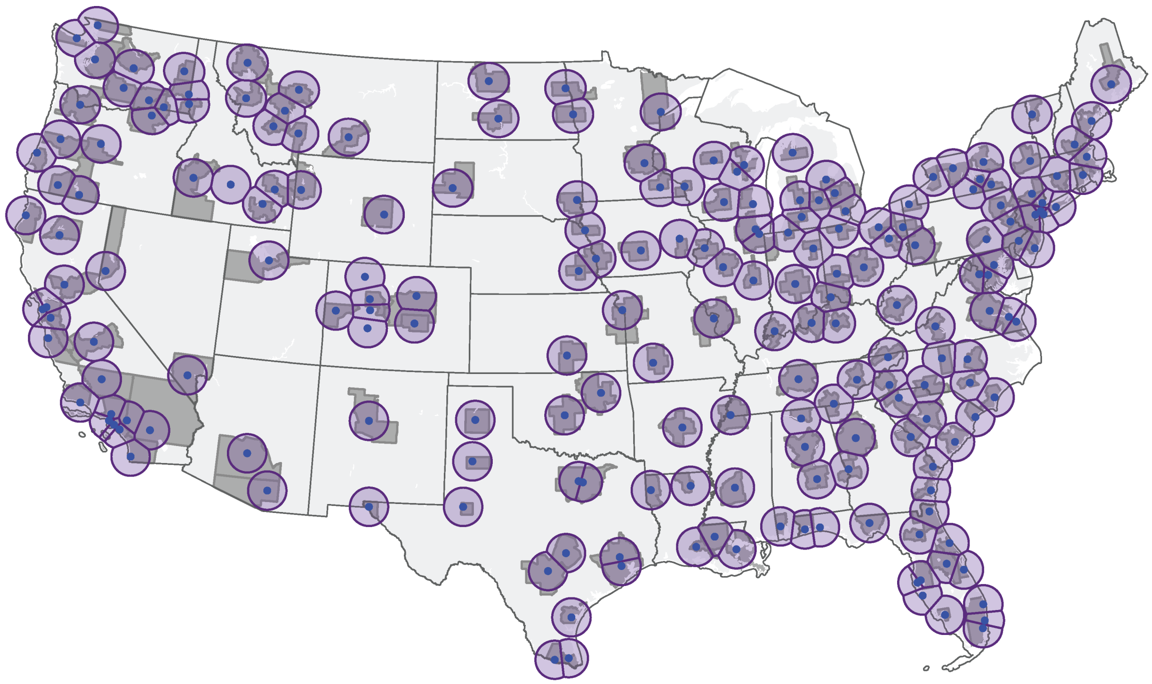

Figure 6: Map of the metropolitan areas defined as the space within 50 miles of the nearest airport that hosts at least 2,500 annual departing passengers from 1990 to 2013. The dot at the center of each area represents the airport. The areas are overlaid on the 2009 CBSAs.